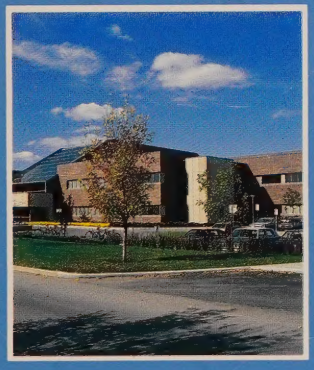
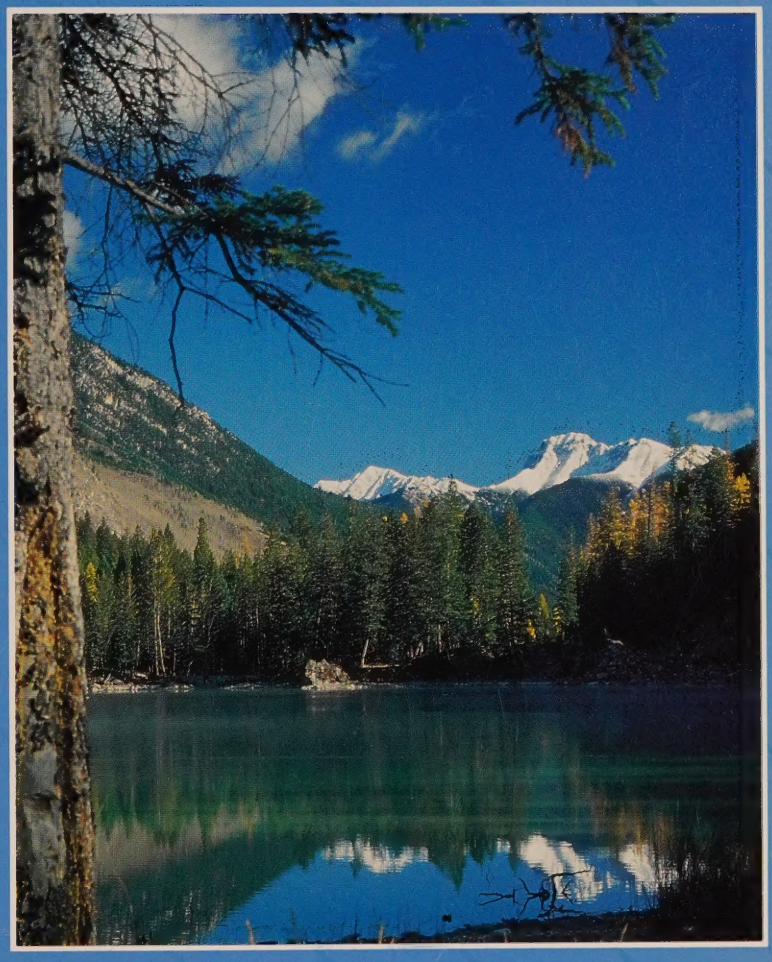
National Hydrology Research Centre (Canada)

Annual Report

Environment Canada | Environnement Canada

NATIONAL HYDROLOGY RESEARCH CENTRE





ANNUAL REPORT

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National Hydrology Research Centre
Annual Report 1987-1988

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Director's Office

Director's Comments

The 1987-88 Annual Report for the National Hydrology Research Centre (NHRC) differs from last year's report in one significant way: it incorporates the activities of the NHRC tenant groups as well as National Hydrology Research Institute (NHRI) divisions.

The other groups located in the Centre, the Water Quality Branch of the Inland Waters Directorate, and the Hydrometeorological Research Division (Canadian Climate Centre) and Meteorological Inspection Office of the Atmospheric Environment Service, are all Environment Canada groups, although they report through different line management than NHRI. However, they have agreed to report their work through this consolidated report rather than individually. This reporting system is more than simply a convenience; rather, it is representative of the interaction the groups enjoy within the Centre. NHRC is, in a very real sense, an Environment Canada research centre, and the interactions between the groups are necessary to solve some of the complex environmental issues we face today.

With respect to the National Hydrology Research Institute, the year 1987-88 has been one of consolidation and growth. A new issues-oriented programme set, new equipment, and a revision of the management structure all have enhanced NHRI's ability to address water research and management problems.

One of the year's many highlights was the National Hydrology Research Institute's planning retreat for both scientists and management personnel at Waskesiu, Saskatchewan. National and international hydrological issues were reviewed and a programme was defined to address these concerns within Environment Canada's mandate for NHRI. The revised programme set which resulted from the meeting became the basis for NHRI's research action plan for the 1988-89 year. The new programme set was presented to senior management at a Science Forum, and won considerable support.

Advances in research necessitate state-of-the-art technology. This year, the acquisition of a Scanning Electron Microscope and the completion of the Facility for Indoor Aquifer Testing (FIAT) provided new technology to aid NHRI research in ground-water chemistry, aquatic biology, and ground ice.

During the year, scientific support services, including the Instrument Technology Section and technicians assigned to specific research groups, were consolidated into the Research Support Division. This restructuring will allow for more flexibility and efficiency in supporting the science divisions and in managing technical staff, and will provide staff with better opportunities for career development.

NHRI's Senior Scientist, Dr V. Klemeš, assumed a prestigious position this year when he was elected President of the International Association of Hydrological Sciences. Dr Klemeš has been in contact with scientists the world over as a result of this position. NHRC has benefitted, too, from the visits Dr Klemeš has been able to arrange with some of these eminent scientists.

The addition of new staff has been another highlight of the past year. Dr K. J. D. Ridley and Dr Y. T. J. Kwong have joined the Ground Water Division, and several new technical staff have joined the Research Support Division. The Hydrometeorological Research Division of the Canadian Climate Centre (AES) also increased its staff from two to eight, including two research scientists and two meteorologists.

The benefits of NHRC's location in the Innovation Place research park on the University of Saskatchewan campus have also become apparent. NHRC has been able to take advantage of the proximity of the other scientists on campus, many of whom work in fields complementary to hydrology. This co-location is of great benefit because it facilitates the interdisciplinary work necessary to solve many of today's hydrological problems. Our scientists have enjoyed access to col-

Staff

Director's Office

Dr T.M. Dick
S. Hansen (Secretary)
Dr V. Klemeš
L. Watson

leagues within the Saskatchewan Research Council, Agriculture Canada, the Canadian Wildlife Service, and, of course, the university itself.

In addition, three NHRI scientists, Dr W. Nicholaichuk, Dr T. Prowse, and Dr P. Marsh, have been appointed adjunct professors of the University of Saskatchewan. This appointment makes them associate members of the university faculty, and allows them to supervise graduate students. The appointments reflect the university's high regard for our scientists and their work.

Senior Scientist

The Centre was honoured during the year by the election of Dr V. Klemeš to the Presidency of the International Association of Hydrological Sciences (IAHS), part of the International Union of Geodesy and Geophysics (IUGG) of the International Council of Scientific Unions (ICSU), at the IAHS meeting in Vancouver in the fall of 1987. The duties of President require travel to a number of countries to chair meetings, to meet other hydrologists and to present invited lectures.

Dr Klemeš has continued his research into the stochastic properties of cumulative processes of higher orders. Results show that the linkage between geophysical, biophysical, and socio-economic processes often has the form of a hierarchy of cumulative processes, e.g. the cyclic levels of a lake are the net sum of random supplies by rain and withdrawals by evaporation. This hierarchical linkage introduces a quasi-cyclic pattern into their behaviour over time which may be important for forecasting as well as for interpreting historical records (e.g. reconstructing past climates). A proposed mathematical description of the mechanism shows that the apparent periodicity induced into the time series is a function of the sample size. Both observed and hypothetical examples of the mechanisms have been described and the general consequences for analysis of empirical time series discussed.

Some hydrological aspects of the drought phenomenon have also been analysed and the following conclusions reached: (1) hydrology can best contribute to short-to-mid-term forecasting of droughts but can offer little for long-term forecasting, which must draw on mechanisms of large-scale climatic fluctuations; (2) hydrological processes influence drought through storage mechanisms; (3) the features of individual droughts are related to the type of the storage mechanism involved, i.e. the type of the input process, the size and geometry of the storage system, and its release mechanism.

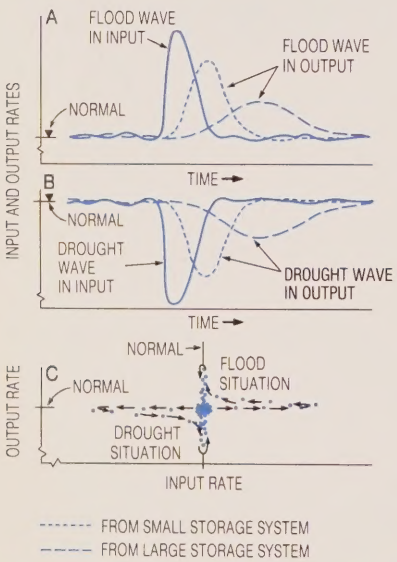
Library

During the first full year of operation, library staff completed the cataloguing of all materials and entered records into an automated library catalogue. All publications are now accessible by author, title, subject, and keyword searching. The catalogue continues to grow rapidly as the collection is developed by including recently released books as well as standard references.

The serials list increased by twenty titles to include new journals in the field of water resources and to accommodate new directions in the scientific programmes. We also established on-line contact with all of the major North American scientific data bases so that on-line literature searching can now be carried out on-site.

In June, the library organized a special educational programme for four-to-six year old children as part of Environment Week activities. Approximately two hundred children visited the Centre with their teachers each day and spent an hour in the library learning about the environment.

SCHEMATIC REPRESENTATION OF ROUTING EFFECT OF A STORAGE RESERVOIR:
A - "Flood Wave" routing, B - "Drought Wave" routing, C - Input-output relationship for cases A and B



Surface Water Division

The three phases of surface water (vapour, liquid, and solid) are the focus of the research programme of the Surface Water Division. Of particular interest is the possible impact of climate change on water supply.

On the Prairies, snow is a vital component in restoring soil moisture and in the longer-term availability of water for agriculture. Thus, part of the programme of the Prairie Hydrology Section deals with snow management and remote sensing of the snowpack. Another part investigates the distribution and pathways of herbicides and nutrients as a result of irrigation. Water loss through evaporation is being evaluated using the Complementary Relationship Areal Evapotranspiration (CRAE) model.

The Mountain Hydrology Section is mainly concerned with snow and ice, the solid phase of the hydrological cycle. Investigations in the Coast Mountains and Rockies are revealing changes in the state of that portion of our water resource held in the glacier reservoirs; of importance primarily for irrigation and hydro-power generation. Studies of winter, summer and net glacier mass balance continued on Sentinel, Helm, Place, and Peyto Glaciers. The mountain snowpack at Sunshine, Alberta provided a field laboratory for an investigation of the dielectrical properties of snow. Of importance here is the role that microstructure and water content play in affecting satellite signals used to observe and measure the seasonal snow cover.

Dry snow and glacier ice trap and preserve a number of atmospheric constituents and climatic signals. These aerosols and gases can be retrieved from ice cores and measured. Fractionation of oxygen isotopes provides a temperature signal and the annual snow layers a record of annual precipitation. Measurement techniques are being applied to an ice core record from Mount Logan to provide environmental information over the last 300 years.

Responses to hydrological and climatic conditions in Canada's north may differ markedly from those in the south so it may not be possible to apply existing southern-based models here. Scientists in the Northern Hydrology Section are investigating river ice break-up and ice jamming in the Mackenzie and Liard Rivers. Backwater flooding from such jams frequently lead to the inundation of northern communities. The hydrology and lake regimes of the Mackenzie Delta that could be seriously affected by any regulation of river levels are studied as well as aspects of the energy balance of ice-covered rivers. The Section undertakes lake and river research in Manitoba and Saskatchewan.

The Surface Water Division focusses on one major portion of the hydrological cycle. It complements the work of the other two science divisions which deal with ground water and aquatic ecology.

Prairie Hydrology Section

Snow Management and Meltwater Enhancement

Different swathing and tilling practices affect the amount of snow retained during the winter. This improves the levels of soil moisture during the spring. A co-operative study with Agriculture Canada (B. McConkey) and the University of Saskatchewan, Division of Hydrology (D. Gray), which began in October 1986, determines the effects of various snowmelt enhancement techniques on surface run-off and ground-water recharge.

Four research sites are located in the brown and dark-brown soil zones of Saskatchewan. Over-winter soil moisture changes resulting from snow trapped by tall standing stubble and by subsoiling at different depths and distances are measured. Yields from a fertilized, snow-managed, subsoiled site that received 122 mm of snowmelt infiltration were nearly as abundant as yields from a fallow field. They showed an increase of 1098 kg/ha over undisturbed stubble. It was also observed that subsoiling at a depth of 400 to 600 mm and 0.7 to 0.8 m apart enhances the infiltration characteristics of frozen soil.

Staff

Surface Water Division

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S.C. Bigras
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M. Lapointe
Dr P. Marsh
B. McEwan (Secretary)
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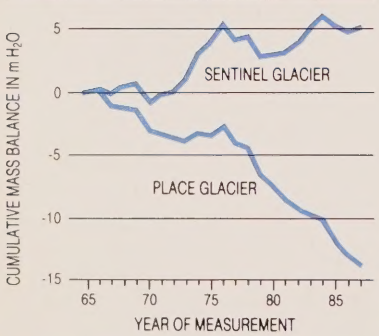
Dr R.I. Perla
Dr A. Wankiewicz

VARIATION IN GLACIER STORAGE
at Sentinel and Place glaciers, B.C.



Microwave Remote Sensing of Snowpack and Flooding

Reliable measurements of snow and soil moisture over large areas are required to determine regional water balances, drought conditions and the likelihood of flooding. A microwave model has been modified to simulate emissions from up to three layers and from five different surfaces of land, water, ice and snow. It is calibrated for Nimbus-7 satellite data of central and southern Manitoba for the winter of 1987-1988.

For the Red River basin of southern Manitoba, the regression of microwave observations with snowpack ground data and with NOAA infrared observations of flooding, show that both snow water equivalent and flooded area can be determined from the microwave observations. However, this is provided that only dry snow conditions (for snowpack) and unfrozen pond conditions (for flooding) are included from the regression, using air temperature as a discriminant.

Herbicide, Nutrient and Water Drainage from an Irrigated Field

Water-resource planning depends very much on knowing how agricultural practices affect the quantity and quality of surface water. In a co-operative project, initiated in 1986 with Agriculture Canada (R. Grover) and the Saskatchewan Research Council (J. Whiting), the amount and quality of irrigation and subsurface drainage water following each rainfall and irrigation event was determined. Results shows that:

- 10.6% of the applied irrigation water (corrugation method) is returned as drainage water;
- of the applied nutrients and chemicals, 0.1% of the nitrogen, 0.22% of the phosphorus, 0.17% of the dicamba, 0.13% of the MCPA, and 0.18% of the diclofop were lost to surface drainage.

These data suggest that herbicide concentrations are well below the acceptable concentration limits of 10,000 ppb for aquatic invertebrates. As in 1986, a major portion of the nutrients and herbicides were lost during the first irrigation.

Complementary Relationship Areal Evapotranspiration (CRAE) Model Evaluation

Current methods for estimating average evaporation, evapotranspiration or transpiration over large areas are very inaccurate. Yet evaporation is a major component of the global water cycle and is particularly important in the Prairies. As one approach to the problem, a co-operative study, with Alberta Environment (F. Davies), Agriculture Canada (C. Chang) and the IWD Water Resources Branch (L. Warner), is underway to evaluate the CRAE model. Results show that the model is extremely sensitive to measured dewpoint temperatures: for each degree change in dewpoint temperature, estimates of evapotranspiration are affected by 10 per cent.

Mountain Hydrology Section

Glacier Mass Balance in Southwestern British Columbia

In order to acquire baseline information on the health of glaciers in the Cordillera and assess the relationships between climate, climate change, glacier health, activity, and water supply, observations are made on three glaciers in the Coast Mountains and one in the Rockies.

Complete mass balance measurements (i.e. winter, summer and net mass balance) were carried out on Sentinel, Helm and Place Glaciers in southwestern British Columbia. Of the three glaciers, Sentinel had a positive mass balance of +0.15 m H_2O while Helm and Place had negative mass balances of –0.79 and –0.85 m H_2O respectively. Because of local factors, Helm Glacier has been rapidly losing area and volume; one-third of its surface area of 2.94 km^2 has been lost since 1977. Although data from Peyto Glacier have not yet been reduced, the mass balance here was also negative. These negative balances mean that water

is being withdrawn from the glacier reservoirs and the glaciers will retreat.

Radio-Frequency Impedance of Snow

To improve the interpretation of remote-sensing signals, the complex impedance of a wide variety of natural and artificially-prepared snow samples was measured in cell volumes $10^5 mm^3$ to $10^6 mm^3$ at 10 kHz to 10 MHz. Independent variables include snow density, temperature and liquid water; the latter is measured using acid dilution. The morphology of disaggregated crystals was recorded on photomicrographs and specimens sectioned to obtain objective stereological parameters. Preliminary results suggest that the complex impedance may provide an index of snow microstructure and a useful tool for ground-truthing.

Ice Core - Climate Change and Atmospheric Chemistry

More information on past climatic and atmospheric conditions in Canada over the last 200 years was revealed from analyses of the Mount Logan ice core. Additional isotopic ($\delta^{18}O$, δD) and chemical analyses confirmed the time scale by establishing the existence of several additional secondary volcanic events. There is evidence of stable isotope perturbations associated with some of the major volcanic (acid) signatures. These perturbations are assumed to be caused by climate, specifically temperature fluctuations. Two assumed climatic extremes, as shown by more negative, decadal-scale oxygen-isotope values occurred in 1705 - 1710 A.D. and between about 1850 and 1860. Dendroclimatic studies from northern Yukon indicate significant cooling at about these periods, suggesting that the ice core oxygen-isotope perturbations are largely temperature induced. The post-1800 A.D. cooling, culminating in what is known as the "year without summer" (1816) in eastern Canada, is not seen in the western proxy data.

The annual precipitation time series was extended back to 1777 A.D. The base of the core is at 1695 A.D. The section from 1880 and 1980 is being used to study in detail what factors may modulate precipitation and also the precipitation teleconnections between this and several other regions. Atmospheric structure is studied through the vertical profiles of oxygen-isotopes ($\delta^{18}O$) and deuterium (δD).

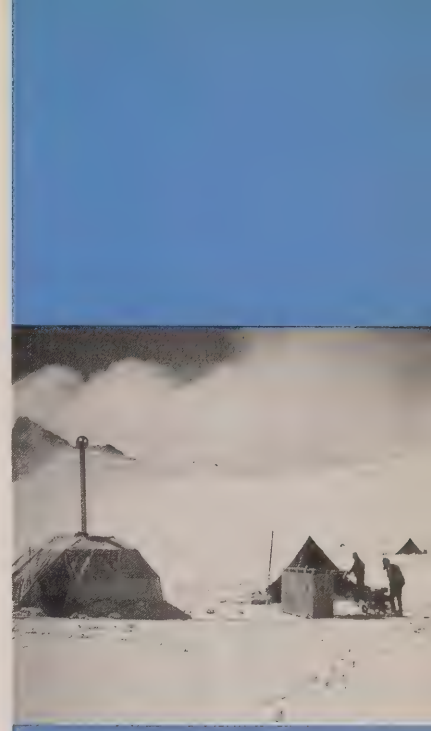
Analyses of the record of common acids in the snow and ice cores do not show any significant increase in the natural background levels of snow acidity.

Northern Hydrology Section

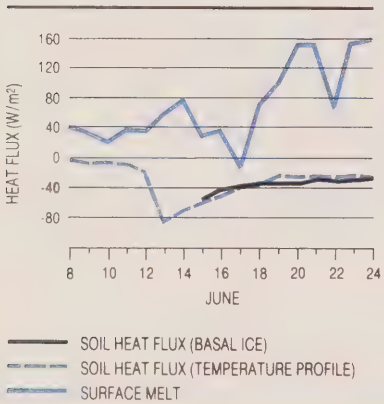
River Ice Break-Up and Ice Jamming

Break-up controls the hydrological regime of most Canadian rivers for lengthy periods each year and contributes to the flood problems of many riverine communities. The entire process, from first ice deterioration to final ice clearance, is poorly understood. To further our knowledge of this process, investigations of break-up and ice jamming on the Liard and Mackenzie Rivers continued during the spring of 1987. Some results of the Yukon Ice Seasonality Experiment were published. The influence of streamflow and ice cover on river hydraulics in a 4.3-km stretch of the Yukon River near Whitehorse have been assessed and observations from three years compared. A new method for measuring river discharge in winter has been developed. A study of river waves, which control the advance of break-up, was initiated with scientists from the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). The ability of a CRREL impulse radar system to measure the thickness of intact and fragmented ice was also tested.

Detailed energy balance experiments of the decaying ice sheet were conducted in conjunction with *in situ* measurements of ice strength (in compression) using a borehole-jack system. Results suggest that the jack can be used to provide an index of ice strength during the decay period.



SOIL HEAT FLUX
throughout the melt period at Resolute, N.W.T.



Backwater Flooding from Ice Jams, Mackenzie Delta, N.W.T.

The processes involved in ice break-up and ice jamming in the Mackenzie Delta were identified and quantified in order to assess their importance to the hydrological regime. The location of frequent ice jams, their formation, composition, growth, the backwater build-up associated with them, and the characteristics of the resulting flow redistribution were all documented. The patterns corresponding to each type of break-up were described in conjuction with the prevailing climatic conditions.

Mackenzie Delta Hydrology, N.W.T.

Since deltas occur at the interface between two very different hydrological systems, river basins and lakes or oceans, their water-level regime is complex. The timing, duration, and frequency of flooding of the Mackenzie Delta lakes by the Mackenzie River and the magnitude of local snow-melt run-off have been investigated: in particular, the relationship between lake sill elevation and flooding characteristics. Indications are that without flooding the high perched lakes in the southern delta would dry up. This is further supported by the results of a five-year microclimatological and water balance study which shows that lake evaporation ranged from 200 to 387 mm per summer. This is always greater than the summer precipitation and sometimes exceeds the annual precipitation. The relative importance of the various water balance components and the rate of sedimentation in Delta lakes are being assessed.

Lake Regimes Study, Mackenzie Delta, N.W.T.

Increased flow regulation of the Mackenzie River main stem could have an impact on the hydrological regime of lakes and channels in the Mackenzie Delta. The relative importance of backwater flooding from ice jams, the processes of inflow, outflow and evaporation, hydrometeorological conditions and physiographic controls have all been studied.

Water Temperature and Heat Fluxes

It is not possible to predict spring break-up and snowmelt run-off, and hence the quantity and timing of streamflow, in permafrost basins. The processes controlling water temperature in ice-covered rivers are being studied in order to develop a model predicting both cross-channel and temporal changes in temperature.

Lake and River Research, Manitoba and Saskatchewan

Improvements in water quality in lakes and rivers can be achieved by reducing man-made nutrient sources or by augmenting the natural sinks. Particular attention is being paid in this study to the role of sedimentation and resuspension in Prairie lakes and reservoirs. Research is underway on the following topics:

- the impact of under-ice baroclinic circulation on the dynamics in Southern Indian Lake
- the quantification of mixed-layer entrainment and sediment resuspension in Prairie lakes
- the nutrient dynamics in a chain of lakes in the Qu'Appelle Valley, Saskatchewan
- the development of engineering design parameters for suspended particle profiling in rivers
- the effects of super critical flow and turbulence on the growth of benthic algae
- the theory of spurious relations in science and engineering.

Ground Water Division

The Ground Water Division has its main focus in those areas involving man's interaction with the hydrological cycle. Here, the need is to understand the key physical and chemical processes that govern the nature and behaviour of ground water and to develop methods for predicting them. Investigations are designed to describe and assess the effects of industry, agriculture, and urbanization on ground-water quality. In particular, this includes the contamination of ground water by toxic substances resulting from agricultural and waste management practices, and climatic variability induced by man's activities.

A special indoor aquifer testing facility has been constructed which provides a controlled environment for investigating the behaviour of contaminants, such as industrial wastes and pesticides, as they move through the subsurface and for validating and calibrating new and existing models. Another major area of investigation is the behaviour of ground water in permafrost regions. Particular emphasis is being placed on the impacts of contaminants in permafrost regions and on the potentially major impacts of climate variability on permafrost. Other studies involve field investigations of pesticides in ground water, the migration of contaminants from landfill sites and ways to contain them, and aspects of deep-well disposal of liquid wastes.

The major scientific thrust of the Ground Water Division's programmes is to develop a better understanding of the basic physical and chemical processes influencing the behaviour of ground water and its interactions with the surrounding aquifer materials. The recently acquired scanning electron microscope (SEM) and X-ray diffractometer (XRD) are essential tools for studying these processes and will be invaluable for the GWD's future activities. The interactions between ground water and other parts of the hydrological cycle play a major role in resolving questions associated with the contamination of surface- and ground-water bodies, toxic-chemical migration, acid precipitation effects, water supply and ground-water protection.

Specific projects include a study of contaminant transport in fractured porous media using landfill sites in various Canadian urban centres; ground-water behaviour in Wood Buffalo National Park as it may affect Whooping Cranes; and mine drainage and the mathematical modelling of ground water and streamflow.

Interaction of Surface and Ground Water

Surface-water/ground-water interactions play an important role in studying water balances, toxic-chemical migration, acid-rain impacts, water supply via artificial recharge, the development of ground-water protection guidelines, and other areas. The Ground Water Division is undertaking the following research in order to address some of these specific concerns:

Contaminant Transport in Fractured Porous Media

A collaborative project to study the behaviour and transport of contaminants in a fractured, smectitic, clay environment is being discussed with the City of Regina. The study will provide a better understanding of and insight into the interaction of a contaminating fluid, such as leachate, with the solid mineral phase, and the physical and chemical transport of contaminants from a source area like a landfill site, through a fractured, porous media. Four phases are being proposed: a) large-scale field testing; b) extensive laboratory testing; c) correlation of laboratory and field data by verification through sampling of soil beneath a landfill site; and d) development of a coupled transport model in fractured clay.

Water Sources in Wood Buffalo National Park

The preservation of the endangered Whooping Crane population is critically dependent on the long-term stability of

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water levels in the ponds which dot the Whooping Crane nesting area in Wood Buffalo National Park. It is thought that ground water may play a major role in controlling these levels.

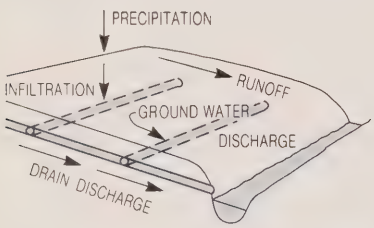
Using hydrogeochemical and isotopic data, as well as hydrography, aerial photography and remote sensing techniques, the Ground Water Division is investigating the ground-water recharge/discharge characteristics of the Whooping Crane nesting area. The study in 1987/88 consisted of continued water level elevation measurements in the ponds and in piezometers installed in the area, and a remote-sensing study of the Wood Buffalo Park using Landsat and NOAA imagery to delineate areas of groundwater discharge, and to quantify the effects of ground water on the Whooping Cranes' nesting ponds. This study will continue to the end of fiscal year 1990/91.

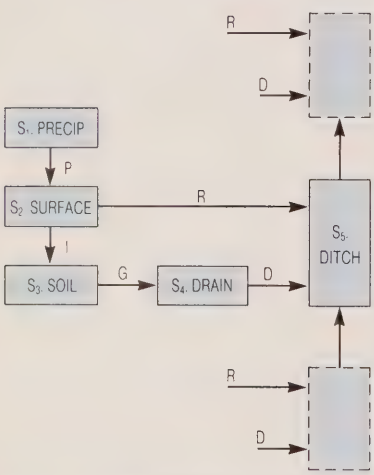
Mathematical Modelling of Streamflow Generation from Drained Fields

Digital models of soil-moisture movement have been developed in order to assess the effects of drainage improvements on a basin hydrograph. Elements of the hydrological cycle which are directly affected by drainage improvements have been identified and a model of this part of the hydrological cycle has been constructed, which permits the simulation of specific drainage improvements, and assessment of the effect of drainage improvement on the total discharge from a drained field for a given precipitation input.

Application of the model suggests that in the course of the drainage history of a swamp, for example, increased peak flows can be expected in the early stages owing to improved surface drainage. Subsequently, improvement in soil drainage and aeration will cause peak flows to diminish. Comparable models can be developed to model the impacts of drainage and climatic change on Prairie lakes and potholes.

SECTION OF THE HYDROLOGICAL CYCLE AFFECTED BY DRAINAGE IMPROVEMENTS





Ground-Water Contamination

The effect of aquifer materials on the chemistry of polluted water is not sufficiently well-known to permit prediction of ground-water quality as a function of time or space yet the pollution of ground water by toxic substances is a serious contemporary problem. The recently acquired SEM and XRD, together with facilities such as FIAT will enable the Ground Water Division to study the detailed mechanisms whereby contaminants interact with the surrounding aquifer materials. Initially, attention will focus on fluvial bed combustion wastes. Future studies will investigate pesticides and other organic and inorganic contaminants.

Facility for Indoor Aquifer Testing (FIAT)

A large indoor test facility has been developed for the study of flow through porous media under controlled laboratory conditions and on a scale large enough to minimize container effects. FIAT consists of a fibreglass tank with access ports at 11 different depths, more close to the surface than at depth. The internal systems consist of dual water-sampling filters at 10 different depths, thermistors at each depth, and pressure transducer pairs for adjusting the sampling rate to minimize flow disturbance. As well, there is a drain system to adjust the water table, and a gutter to eliminate flow along the tank walls. An integral part of the system is the precipitation applicator, its control system, rain tank and head tank. The rain system, sample collection pumps and pressure transducers will all be controlled by a computer system. Testing of the whole system will begin in May, 1988.

Acid Neutralization in Ground-Water Flow Systems, Turkey Lakes, Ontario

As a result of the Turkey Lakes watershed GWD research programme in Ontario, it has been established that the ground-water aquifer system plays a major role in ameliorating the impacts of

is being withdrawn from the glacier reservoirs and the glaciers will retreat.

Radio-Frequency Impedance of Snow

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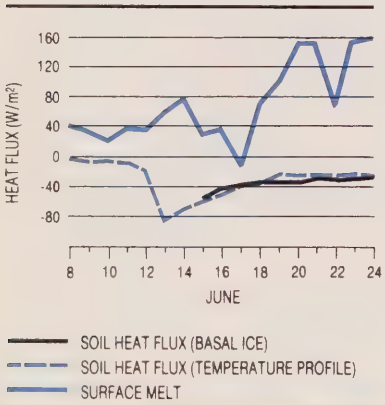
Northern Hydrology Section

River Ice Break-Up and Ice Jamming

Break-up controls the hydrological regime of most Canadian rivers for lengthy periods each year and contributes to the flood problems of many riverine communities. The entire process, from first ice deterioration to final ice clearance, is poorly understood. To further our knowledge of this process, investigations of break-up and ice jamming on the Liard and Mackenzie Rivers continued during the spring of 1987. Some results of the Yukon Ice Seasonality Experiment were published. The influence of streamflow and ice cover on river hydraulics in a 4.3-km stretch of the Yukon River near Whitehorse have been assessed and observations from three years compared. A new method for measuring river discharge in winter has been developed. A study of river waves, which control the advance of break-up, was initiated with scientists from the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). The ability of a CRREL impulse radar system to measure the thickness of intact and fragmented ice was also tested.

Detailed energy balance experiments of the decaying ice sheet were conducted in conjunction with *in situ* measurements of ice strength (in compression) using a borehole-jack system. Results suggest that the jack can be used to provide an index of ice strength during the decay period.

SOIL HEAT FLUX
throughout the melt period at Resolute, N.W.T.



Backwater Flooding from Ice Jams, Mackenzie Delta, N.W.T.

The processes involved in ice break-up and ice jamming in the Mackenzie Delta were identified and quantified in order to assess their importance to the hydrological regime. The location of frequent ice jams, their formation, composition, growth, the backwater build-up associated with them, and the characteristics of the resulting flow redistribution were all documented. The patterns corresponding to each type of break-up were described in conjuction with the prevailing climatic conditions.

Mackenzie Delta Hydrology, N.W.T.

Since deltas occur at the interface between two very different hydrological systems, river basins and lakes or oceans, their water-level regime is complex. The timing, duration, and frequency of flooding of the Mackenzie Delta lakes by the Mackenzie River and the magnitude of local snow-melt run-off have been investigated: in particular, the relationship between lake sill elevation and flooding characteristics. Indications are that without flooding the high perched lakes in the southern delta would dry up. This is further supported by the results of a five-year microclimatological and water balance study which shows that lake evaporation ranged from 200 to 387 mm per summer. This is always greater than the summer precipitation and sometimes exceeds the annual precipitation. The relative importance of the various water balance components and the rate of sedimentation in Delta lakes are being assessed.

Lake Regimes Study, Mackenzie Delta, N.W.T.

Increased flow regulation of the Mackenzie River main stem could have an impact on the hydrological regime of lakes and channels in the Mackenzie Delta. The relative importance of backwater flooding from ice jams, the processes of inflow, outflow and evaporation, hydrometeorological conditions and physiographic controls have all been studied.

Water Temperature and Heat Fluxes

It is not possible to predict spring break-up and snowmelt run-off, and hence the quantity and timing of streamflow, in permafrost basins. The processes controlling water temperature in ice-covered rivers are being studied in order to develop a model predicting both cross-channel and temporal changes in temperature.

Lake and River Research, Manitoba and Saskatchewan

Improvements in water quality in lakes and rivers can be achieved by reducing man-made nutrient sources or by augmenting the natural sinks. Particular attention is being paid in this study to the role of sedimentation and resuspension in Prairie lakes and reservoirs. Research is underway on the following topics:

- the impact of under-ice baroclinic circulation on the dynamics in Southern Indian Lake
- the quantification of mixed-layer entrainment and sediment resuspension in Prairie lakes
- the nutrient dynamics in a chain of lakes in the Qu'Appelle Valley, Saskatchewan
- the development of engineering design parameters for suspended particle profiling in rivers
- the effects of super critical flow and turbulence on the growth of benthic algae
- the theory of spurious relations in science and engineering.

Ground Water Division

The Ground Water Division has its main focus in those areas involving man's interaction with the hydrological cycle. Here, the need is to understand the key physical and chemical processes that govern the nature and behaviour of ground water and to develop methods for predicting them. Investigations are designed to describe and assess the effects of industry, agriculture, and urbanization on ground-water quality. In particular, this includes the contamination of ground water by toxic substances resulting from agricultural and waste management practices, and climatic variability induced by man's activities.

A special indoor aquifer testing facility has been constructed which provides a controlled environment for investigating the behaviour of contaminants, such as industrial wastes and pesticides, as they move through the subsurface and for validating and calibrating new and existing models. Another major area of investigation is the behaviour of ground water in permafrost regions. Particular emphasis is being placed on the impacts of contaminants in permafrost regions and on the potentially major impacts of climate variability on permafrost. Other studies involve field investigations of pesticides in ground water, the migration of contaminants from landfill sites and ways to contain them, and aspects of deep-well disposal of liquid wastes.

The major scientific thrust of the Ground Water Division's programmes is to develop a better understanding of the basic physical and chemical processes influencing the behaviour of ground water and its interactions with the surrounding aquifer materials. The recently acquired scanning electron microscope (SEM) and X-ray diffractometer (XRD) are essential tools for studying these processes and will be invaluable for the GWD's future activities. The interactions between ground water and other parts of the hydrological cycle play a major role in resolving questions associated with the contamination of surface- and ground-water bodies, toxic-chemical migration, acid precipitation effects, water supply and ground-water protection.

Specific projects include a study of contaminant transport in fractured porous media using landfill sites in various Canadian urban centres; ground-water behaviour in Wood Buffalo National Park as it may affect Whooping Cranes; and mine drainage and the mathematical modelling of ground water and streamflow.

Interaction of Surface and Ground Water

Surface-water/ground-water interactions play an important role in studying water balances, toxic-chemical migration, acid-rain impacts, water supply via artificial recharge, the development of ground-water protection guidelines, and other areas. The Ground Water Division is undertaking the following research in order to address some of these specific concerns:

Contaminant Transport in Fractured Porous Media

A collaborative project to study the behaviour and transport of contaminants in a fractured, smectitic, clay environment is being discussed with the City of Regina. The study will provide a better understanding of and insight into the interaction of a contaminating fluid, such as leachate, with the solid mineral phase, and the physical and chemical transport of contaminants from a source area like a landfill site, through a fractured, porous media. Four phases are being proposed: a) large-scale field testing; b) extensive laboratory testing; c) correlation of laboratory and field data by verification through sampling of soil beneath a landfill site; and d) development of a coupled transport model in fractured clay.

Water Sources in Wood Buffalo National Park

The preservation of the endangered Whooping Crane population is critically dependent on the long-term stability of

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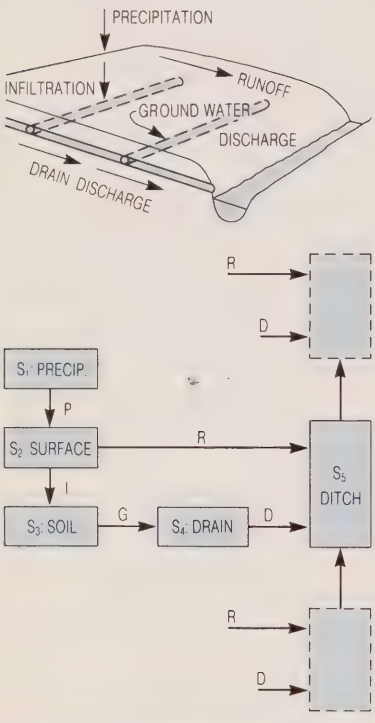
SECTION OF THE HYDROLOGICAL CYCLE AFFECTED BY DRAINAGE IMPROVEMENTS



water levels in the ponds which dot the Whooping Crane nesting area in Wood Buffalo National Park. It is thought that ground water may play a major role in controlling these levels.

Using hydrogeochemical and isotopic data, as well as hydrography, aerial photography and remote sensing techniques, the Ground Water Division is investigating the ground-water recharge/discharge characteristics of the Whooping Crane nesting area. The study in 1987/88 consisted of continued water level elevation measurements in the ponds and in piezometers installed in the area, and a remote-sensing study of the Wood Buffalo Park using Landsat and NOAA imagery to delineate areas of ground-water discharge, and to quantify the effects of ground water on the Whooping Cranes' nesting ponds. This study will continue to the end of fiscal year 1990/91.

Mathematical Modelling of Streamflow Generation from Drained Fields

Digital models of soil-moisture movement have been developed in order to assess the effects of drainage improvements on a basin hydrograph. Elements of the hydrological cycle which are directly affected by drainage improvements have been identified and a model of this part of the hydrological cycle has been constructed, which permits the simulation of specific drainage improvements, and assessment of the effect of drainage improvement on the total discharge from a drained field for a given precipitation input.

Application of the model suggests that in the course of the drainage history of a swamp, for example, increased peak flows can be expected in the early stages owing to improved surface drainage. Subsequently, improvement in soil drainage and aeration will cause peak flows to diminish. Comparable models can be developed to model the impacts of drainage and climatic change on Prairie lakes and potholes.

Ground-Water Contamination

The effect of aquifer materials on the chemistry of polluted water is not sufficiently well-known to permit prediction of ground-water quality as a function of time or space yet the pollution of ground water by toxic substances is a serious contemporary problem. The recently acquired SEM and XRD, together with facilities such as FIAT will enable the Ground Water Division to study the detailed mechanisms whereby contaminants interact with the surrounding aquifer materials. Initially, attention will focus on fluvial bed combustion wastes. Future studies will investigate pesticides and other organic and inorganic contaminants.

Facility for Indoor Aquifer Testing (FIAT)

A large indoor test facility has been developed for the study of flow through porous media under controlled laboratory conditions and on a scale large enough to minimize container effects. FIAT consists of a fibreglass tank with access ports at 11 different depths, more close to the surface than at depth. The internal systems consist of dual water-sampling filters at 10 different depths, thermistors at each depth, and pressure transducer pairs for adjusting the sampling rate to minimize flow disturbance. As well, there is a drain system to adjust the water table, and a gutter to eliminate flow along the tank walls. An integral part of the system is the precipitation applicator, its control system, rain tank and head tank. The rain system, sample collection pumps and pressure transducers will all be controlled by a computer system. Testing of the whole system will begin in May, 1988.

Acid Neutralization in Ground-Water Flow Systems, Turkey Lakes, Ontario

As a result of the Turkey Lakes watershed GWD research programme in Ontario, it has been established that the ground-water aquifer system plays a major role in ameliorating the impacts of

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HYDROLOGIC MODEL
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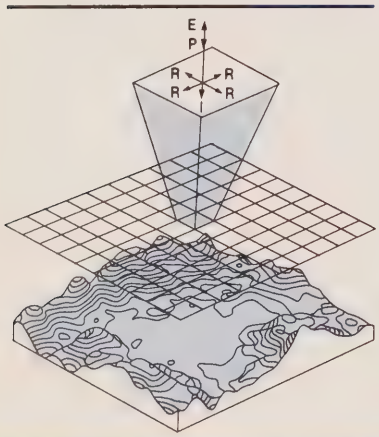

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METEOROLOGICAL INSPECTION OFFICE

The Saskatchewan Inspection Office of the Atmospheric Environment Service is responsible for the installation, maintenance, and inspection of weather stations in Saskatchewan and selected sites in the Northwest Territories. The office is staffed by three meteorological inspectors, and two electronic technicians.

Travel occupies a large part of the office's time. During this past fiscal year the staff logged in excess of 160000 km by road and by air getting to and from the locations to be visited.

Its area comprises 23 mainline weather stations, such as Saskatoon and Regina, seven automatic weather stations, located in towns like Eastend and Uranium City, and approximately 240 volunteer weather observers, situated in small towns and on farms around the province.

As in previous years, all mainline stations were visited regularly in 1987-88 to ensure continuity and completeness of data. A total of 48 inspections were carried out at these locations, with the climate network receiving 195 visits. Some sites were selected for upgrading of facilities and others received completely new facilities.

Each visit to a mainline station requires approximately a week of time in order to complete a full inspection of the equipment and programmes. Inspections of automatic weather stations are shorter, usually only a day, but more frequent, twice per station per year.

Nine stations are operated in total or in part by contract weather observers. Another facet of our job is the on-the-job training and certification of these people. The inspectors spent about four weeks on this task at various locations in Saskatchewan.

The electronic technicians share responsibility for the maintenance of the electronics at the seven automatic weather stations; the weather radar equipment at Elbow, Saskatchewan; and the weather radio equipment at the Saskatoon Airport. This responsibility includes monitoring and maintenance of the equipment. Approximately 48 visits were made to the automatic stations on a scheduled basis, with other visits as necessitated by failures. The radar site at Elbow is inspected bi-weekly, and on an emergency basis as required.

One of the electronic technicians spent four months at Resolute Bay, N.W.T. as part of the inspection office's commitment to staffing an electronic technician position in the High Arctic.

Other projects for the year 1987/88 included the installation of Campbell Scientific weather equipment at Meadow Lake and Nipawin, the relocation of climatological stations at Weyburn and Outlook, upgrading of instrument areas at Resolute Bay, N.W.T., Yorkton, Saskatoon, Wynyard and Prince Albert, Saskatchewan, and the installation of new operations buildings at Nipawin and Wynyard, Saskatchewan.

AES also maintains an Air Quality Monitoring station at Cree Lake, Saskatchewan, which is visited four times annually to ensure the equipment is operating properly, and that staff continue to adhere to established practices. The air quality programme also requires that two inspectors each spend a week on course yearly to refresh their knowledge and skills with regard to this high-profile study.

Each year selected climatological stations are given "awards" during Environment Week. This year awards were made to six volunteer weather observers for both long service and excellence of reports.

Although field work accounts for nearly 75% of the workload of this office, the remainder of the time is well spent. Field equipment is repaired and calibrated; work plans are prepared, modified and executed; and supplies are procured in order to prepare for trips. This office maintains four vehicles, and our responsibility includes insuring that they are road-worthy at all times. We process invoices for payment; deal with contrac-

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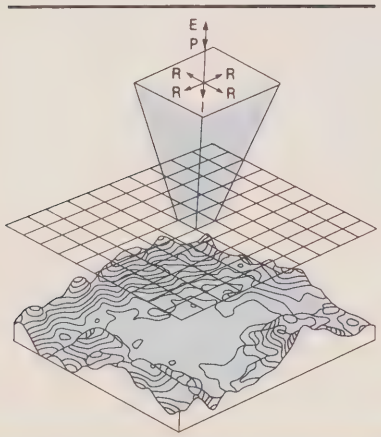

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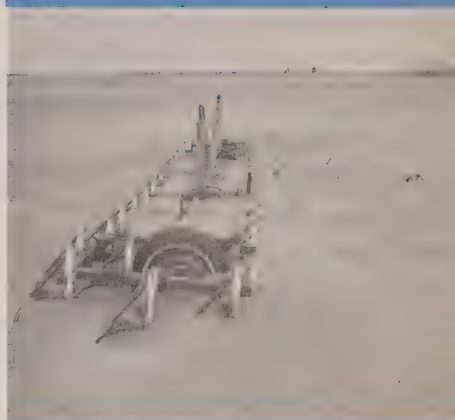
Efforts are underway to upgrade the Elbow radar so that radar data can be archived on an on-going basis. A number of options for accomplishing this upgrade were reviewed and implementation plans were developed in collaboration with the Central Region of AES. Plans were developed in consultation with the Saskatchewan Water Corporation and the Irrigation Development Centre for an Irrigation Scheduling Information System based on the radar-derived precipitation patterns from the Elbow radar.

The Division has been participating in the development of a programme for Extreme Weather Research for the Prairies. This will be a co-operative venture between the Alberta Research Council, the University of Alberta, the Saskatchewan Research Council, and the Atmospheric Environment Service.



METEOROLOGICAL INSPECTION OFFICE

The Saskatchewan Inspection Office of the Atmospheric Environment Service is responsible for the installation, maintenance, and inspection of weather stations in Saskatchewan and selected sites in the Northwest Territories. The office is staffed by three meteorological inspectors, and two electronic technicians.

Travel occupies a large part of the office's time. During this past fiscal year the staff logged in excess of 160000 km by road and by air getting to and from the locations to be visited.

Its area comprises 23 mainline weather stations, such as Saskatoon and Regina, seven automatic weather stations, located in towns like Eastend and Uranium City, and approximately 240 volunteer weather observers, situated in small towns and on farms around the province.

As in previous years, all mainline stations were visited regularly in 1987-88 to ensure continuity and completeness of data. A total of 48 inspections were carried out at these locations, with the climate network receiving 195 visits. Some sites were selected for upgrading of facilities and others received completely new facilities.

Each visit to a mainline station requires approximately a week of time in order to complete a full inspection of the equipment and programmes. Inspections of automatic weather stations are shorter, usually only a day, but more frequent, twice per station per year.

Nine stations are operated in total or in part by contract weather observers. Another facet of our job is the on-the-job training and certification of these people. The inspectors spent about four weeks on this task at various locations in Saskatchewan.

The electronic technicians share responsibility for the maintenance of the electronics at the seven automatic weather stations; the weather radar equipment at Elbow, Saskatchewan; and the weather radio equipment at the Saskatoon Airport. This responsibility includes monitoring and maintenance of the equipment. Approximately 48 visits were made to the automatic stations on a scheduled basis, with other visits as necessitated by failures. The radar site at Elbow is inspected bi-weekly, and on an emergency basis as required.

One of the electronic technicians spent four months at Resolute Bay, N.W.T. as part of the inspection office's commitment to staffing an electronic technician position in the High Arctic.

Other projects for the year 1987/88 included the installation of Campbell Scientific weather equipment at Meadow Lake and Nipawin, the relocation of climatological stations at Weyburn and Outlook, upgrading of instrument areas at Resolute Bay, N.W.T., Yorkton, Saskatoon, Wynyard and Prince Albert, Saskatchewan, and the installation of new operations buildings at Nipawin and Wynyard, Saskatchewan.

AES also maintains an Air Quality Monitoring station at Cree Lake, Saskatchewan, which is visited four times annually to ensure the equipment is operating properly, and that staff continue to adhere to established practices. The air quality programme also requires that two inspectors each spend a week on course yearly to refresh their knowledge and skills with regard to this high-profile study.

Each year selected climatological stations are given "awards" during Environment Week. This year awards were made to six volunteer weather observers for both long service and excellence of reports.

Although field work accounts for nearly 75% of the workload of this office, the remainder of the time is well spent. Field equipment is repaired and calibrated; work plans are prepared, modified and executed; and supplies are procured in order to prepare for trips. This office maintains four vehicles, and our responsibility includes insuring that they are road-worthy at all times. We process invoices for payment; deal with contrac-

tors when weather stations are under construction; and respond to telephone requests for replacement equipment. We are generally involved in the development of weather stations, from the drawing of blueprints, to the trenching of cables and installation of equipment, to the final finished product, and this involves a great deal of planning to ensure that all the requirements are met.

In sum, the 1987/88 year was typical. We spent a lot of time "on-the-road", completing scheduled inspections, visiting weather reporting stations and completing projects to improve existing facilities. Unscheduled visits were kept to a minimum. 1988/89 is shaping up to be another busy year, with more projects coming on stream, and a repeat of the scheduled inspections and visits.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GROUND WATER

AQUATIC ECOLOGY

NHRC 87/88


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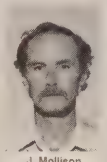
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P.W. Cheung


D. Schroeder


K. Best

HYDROMETEOROLOGICAL RESEARCH

METEOROLOGICAL INSPECTION


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RESEARCH SUPPORT

ATMOSPHERIC ENVIRONMENT

WATER QUALITY

Publications and Reports

Adams, W.P., Prowse, T.D. and Granberg, H., 1987. Observations on floating snowpacks: lakes, rivers and the sea. In - Snow Property Measurement Workshop, 1-3 April 1985, Chateau Lake Louise, Alberta, Canada, P.R. Kry (Compiler), Associate Committee on Geotechnical Research Technical Memorandum No.140, National Research Council of Canada (NRCC 27594), Ottawa, Ontario, April, 313-346

Alford, M.E. and Carmack, E.C., 1987. Observations on ice cover and streamflow in the Yukon River near Whitehorse during 1983/84. NHRI Paper No.32, National Hydrology Research Institute, IWD Scientific Series No.152, Inland Waters/Lands Directorate, Environment Canada, Saskatoon, Saskatchewan, 63 pp.

Alford, M.E. and Carmack, E.C., 1987. Observations on ice cover and streamflow in the Yukon River near Whitehorse during 1984/85. NHRI Paper No.34, National Hydrology Research Institute, IWD Scientific Series No.155, Inland Waters/Lands Directorate, Environment Canada, Saskatoon, Saskatchewan, 24 pp.

Banner, J.A., 1986. Time lapse photography - a ten year update. Proceedings of Inland Waters Directorate Instrumentation Workshop '86, 13-14 May 1986, Burlington, Ontario, Inland Waters Directorate, Environment Canada, Ottawa, Ontario, abstract, 15

Bigras, S.C., 1986. Instrumentation associated with the Mackenzie Delta lake regimes study. Proceedings of Inland Waters Directorate Instrumentation Workshop '86, 13-14 May 1986, Burlington, Ontario, Inland Waters Directorate, Environment Canada, Ottawa, Ontario, abstract, 14

Bigras, S.C., 1987. Lake regimes, Mackenzie Delta, N.W.T., 1984. NHRI Contribution No.87005, Surface Water Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, April, 52 pp.

Bothwell, M., 1987. Phosphorus control of algal production in the Thompson River, British Columbia. NHRI Contribution No.87002, Aquatic Ecology Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, May, 41 pp.

Campbell, C.A., Selles, F., McConkey, B., Zentner, R.P., Nicholaichuk, W., Biederbeck, V.O. and Schnitzer, M., 1987. Interaction of fertilizer N and P and snow conservation on yield of spring and winter wheat in southwestern Saskatchewan. 1987 Annual Report, Project 22310-1580-81-51, Potash and Phosphate Institute, Agriculture Canada Research Station, Swift Current, Saskatchewan, 51 pp.

Canada, Environment Canada, 1987. National Hydrology Research Institute - Annual Report 1986 - 87. National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, 24 pp.

Canada, Secretary of State and Energy, Mines and Resources, 1987. Generic terms in Canada's geographical names. Terminology Bulletin No.176, co-published by Secretary of State and Canadian Permanent Committee on Geographical Names, Energy, Mines and Resources Canada, Ottawa, Ontario, 311 pp.

Carmack, E.C., Wiegand, R.C., Marles, E.M., Alford, M.E. and Chamberlain, V.A., 1987. Physical limnology of an ice-covered lake with through-flow: Lake Laberge, Yukon Territory. NHRI Paper No.35, National Hydrology Research Institute, IWD Scientific Series No.157, Inland Waters/Lands Directorate, Environment Canada, Saskatoon, Saskatchewan, 56 pp.

Christie, R.O., 1986. NHRC Branch overview. Proceedings of Inland Waters Directorate Instrumentation Workshop '86, 13-14 May 1986, Burlington, Ontario, Inland Waters Directorate, Environment Canada, Ottawa, Ontario, abstract, 14

Carter, T., 1987. Facility for indoor aquifer testing (F.I.A.T.). NHRI Contribution No.87006, Ground Water Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, 34 pp.

Davis, R.E., Dozier, J. and Perla, R., 1987. Measurement of snow grain properties. In - Seasonal Snowcovers: Physics, Chemistry, Hydrology, H.G. Jones and W.J. Orville-Thomas (Editors), NATO ASI Series, Series C: Mathematical and Physical Sciences, Vol. 211, Proceedings of the NATO Advanced Studies Institute on Chemical Dynamics of Seasonal Snowcovers, 13-25 July 1986, Les Arcs, France, D. Reidel Publishing Co., Dordrecht, 63 -74

Dozier, J., Davis, R.E. and Perla, R., 1987. Snow microstructure measurements using stereology. In - Snow Property Measurement Workshop, 1-3 April 1985, Chateau Lake Louise, Alberta, Canada, P.R. Kry (Compiler), Associate Committee on Geotechnical Research Technical Memorandum No.140, National Research Council of Canada (NRCC 27594), Ottawa, Ontario, April, 59-69

Fogarasi, S. and Mokievsky-Zubok, O., 1987. An analysis of flow data from Sentinel Creek, British Columbia: Part 1. NHRI Contribution No.87012, Surface Water Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, December, 43 pp.

Halstead, E.C., 1986. Ground-water supply, Fraser Lowland, British Columbia. NHRI Paper No.26, National Hydrology Research Institute, IWD Scientific Series No.145, Inland Waters Directorate, Saskatoon, Saskatchewan, 80 pp. + maps

Hess, P.J., 1986. Ground-water use in Canada, 1981. NHRI Paper No.28, National Hydrology Research Institute, IWD Technical Bulletin No.140, Inland Waters Directorate, Environment Canada, Ottawa, Ontario, 43 pp. + maps

Holdsworth, G., 1987. Reviews - Icebergs: a bibliography relevant to eastern Canadian waters. Edited by Lynne M. Howard. Environmental Studies Revolving Funds Report No.030: ESRF, 1986. Softbound. Cdn $55. Arctic, 40(1), March, 87-88

Holdsworth, G., 1987. The surface wave forms on the Ellesmere Island ice shelves and ice islands. In - Workshop on Extreme Ice Features, G.R. Pilkington and B.W. Danielewicz (Compilers), 3-5 November 1986, Banff, Alberta, Snow and Ice Subcommittee, Associate Committee on Geotechnical Research, Technical Memorandum No.141, National Research Council of Canada (NRCC 28003), Ottawa, Ontario, June, 385-403

Hooke, R.LeB., Johnson, G.W., Brugger, K.A., Hanson, B. and Holdsworth, G., 1987. Changes in mass balance, velocity, and surface profile along a flowline on Barnes Ice Cap, 1970-1984. Canadian Journal of Earth Sciences, 24(8), August, 1550-1561

INTERA Technologies Limited, 1987. Feasibility study for a field sampling program to monitor impacts resulting from *in situ* heavy oil subsurface disposal practices. NHRI Contribution No. 88001, Ground Water Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, contract report prepared by Intera Technologies Ltd., Calgary and Ottawa, funded by the Federal Panel on Energy Research and Development (PERD), July, 81 pp.

Jackson, T.A., 1987. Methylation, demethylation, and bio-accumulation of mercury in lakes and reservoirs of northern Manitoba, with particular reference to effects of environmental changes caused by the Churchill-Nelson River diversion: Final report on Project number 2.3 of the study of mercury in northern Manitoba carried out in accordance with the Canada-Manitoba Agreement. In - Technical Appendices to the Summary Report, Volume 2, Canada-Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion, Governments of Canada and Manitoba, 89 pp.

Johnston, L., 1987. Ground water - why worry? NHRI Contribution No.87008, Ground Water Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, 18 pp.

Johnston, L. and Craig, D., 1987. Turkey Lakes water study: hydrogeological instrumentation and aquifer materials. NHRI Contribution No.87004, Ground Water Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, revised edition, 27 pp.

Johnston, L. and Craig, D., 1987. Status report: ground water studies in the acid rain program. NHRI Contribution No.87022, Ground Water Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, 17 September, 17 pp.

Kirkland, R.A. and Gray, C.B.J., 1986. Reconnaissance of the chemical and biological limnology in four large lakes of the Yukon River basin. NHRI Paper No.33, National Hydrology Research Institute, IWD Scientific Series No.153, Inland Waters Directorate, Environment Canada, Saskatoon, Saskatchewan, 23 pp.

Klemeš, V., 1987. Chapter 7. Drought prediction: a hydrological perspective. In - Planning for Drought, D.A. Wilhite, W.E. Easterling and D.W. Wood (Editors), Westview Press, Boulder, Colorado, 81-94

Klemeš, V., 1987. Reply to Comment on "Dilettantism in hydrology: transition or destiny?" by Z.W. Kundzewicz. Water Resources Research, 23(10), October, 2011-2012

Lyon, K.E. and Patterson, R.J., 1986. Retention of ^{137}Cs and ^{90}Sr by mineral sorbents surrounding vitrified nuclear waste. NHRI Paper No.27, National Hydrology Research Institute, IWD Scientific Series No.148, Inland Waters/ Lands Directorate, Ottawa, Ontario, 19 pp.

Marsh, P., 1987. Factors limiting snowmelt runoff in a permafrost environment. Proceedings, 55th Annual Western Snow Conference, 14-16 April 1987, Vancouver, British Columbia, 61-68

Marsh, P., 1987. Grain growth in a wet Arctic snow cover. Cold Regions Science and Technology, 14(1), 23-31

Marsh, P. and Prowse, T.D., 1987. Water temperature and heat flux to the base of river ice covers. Cold Regions Science and Technology, 14(1), 33-50

Marsh, P. and Woo, M.-K., 1987. Soil heat flux, wetting front advance and ice layer growth on cold dry snow covers. In - Snow Property Measurement Workshop, 1-3 April 1985, Chateau Lake Louise, Alberta, Canada, P.R. Kry (Compiler), Associate Committee on Geotechnical Research Technical Memorandum No.140, National Research Council of Canada (NRCC 27594), Ottawa, Ontario, April, 497-524

McNaughton, D., 1987. Ground water issues in the North. NHRI Contribution No.87009, Ground Water Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, 23 pp.

Mokievsky-Zubok, O., 1987. Glacier mass balance for 1986 on Sentinel, Helm and Place Glaciers, British Columbia. Internal Report, Cold Regions Section, Surface Water Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, January, 16 pp.

Nicholaichuk, W., Gray, D.M. and McConkey, B., 1987. Snow management and meltwater enhancement. Report to the Canada/Saskatchewan Economic and Regional Development Fund, Saskatchewan Agriculture, 18 pp.

Nicholaichuk, W., Leyshon, A.J., Jame, Y.W. and Campbell, C.A., 1987. Boron and salinity survey of irrigation projects and the absorption characteristics of some Saskatchewan soils. Canadian Journal of Soil Science, 68(1), 77-90

Nicholson, J.A., Craig, D. and Foster, N.W., 1987. Precipitation, surface and subsurface water chemistry in a tolerant hardwood forest basin. Proceedings, International Symposium on Acidification and Water Pathways, Vol. 1, 4-5 May 1987, Bolkesjø, Norway, 91-100

Ommanney, C.S.L., 1987. Axel Heiberg Island bibliography. In - Field Research on Axel Heiberg Island, N.W.T., Canada: Bibliographies and Data Reports with Appendices of Data from the McGill Subarctic Research Station, Schefferville, P.Q., P. Adams (Editor), McGill Subarctic Research Paper No.41, Axel Heiberg Island Research Report, Miscellaneous Papers No.2, Occasional Paper No.12, Department of Geography, Trent University, Peterborough, Ontario, Centre for Northern Studies and Research, McGill University, Montréal, Quebec, 5-55

Ommanney, C.S.L., 1987. Axel Heiberg Island visitations. In - Field Research on Axel Heiberg Island, N.W.T., Canada: Bibliographies and Data Reports with Appendices of Data from the McGill Subarctic Research Station, Schefferville, P.Q., P. Adams (Editor), McGill Subarctic Research Paper No.41, Axel Heiberg Island Research Report, Miscellaneous Papers No.2, Occasional Paper No.12, Department of Geography, Trent University, Peterborough, Ontario, Centre for Northern Studies and Research, McGill University, Montréal, Quebec, 56-66

Ommanney, C.S.L., 1987. Report of the Advisory Committee on Glaciological and Alpine Nomenclature. Canoma, 13(2), December, 12-16

Perla, R., Davis, R.E., Dozier, J. and LaChapelle, E.R., 1987. Dilution method for measuring liquid water in snow: field tests in a subalpine snowpack. In - Snow Property Measurement Workshop, 1-3 April 1985, Chateau Lake Louise, Alberta, Canada, P.R. Kry (Compiler), Associate Committee on Geotechnical Research Technical Memorandum No.140, National Research Council of Canada (NRCC 27594), Ottawa, Ontario, April, 71-78

Perla, R. and Sommerfeld, R.A., 1986. On the metamorphism, morphology, and microstructure of snow. In - A Merging of Theory and Practice, Proceedings, International Snow Science Workshop, 22-25 October 1986, Lake Tahoe, California, 98-102

Prowse, T.D., 1987. The albedo of break-up ice covers. Proceedings, 44th Annual Eastern Snow Conference, Fredericton, New Brunswick, 192-196

Prowse, T.D., Anderson, J.C. and Smith, R.L., 1987. Discharge measurement during river ice break-up. Proceedings, 43rd Annual Eastern Snow Conference, 5-6 June 1986, Hanover, New Hampshire, 55-69

Prowse, T.D. and Marsh, P., 1987. Atmospheric and hydrothermal heat flows to intact and fragmented ice covers. I.A.H.S. Workshop on River Ice Covers, August 1987, Vancouver, British Columbia, 21 pp.

Prowse, T.D. and Onclin, C.R., 1987. Timing and duration of river ice break-up. Proceedings, 44th Annual Eastern Snow Conference, Fredericton, New Brunswick, 197-202

Raven, K.G., Bottomley, D.J., Sweezey, R.A., Smedley, J.A. and Ruttan, T.J., 1987. Hydrogeological characterization of the East Bull Lake research area. NHRI Paper No.31, National Hydrology Research Institute, IWD Scientific Series No.160, Inland Waters/Lands Directorate, Saskatoon, Saskatchewan, 77 pp.

Sommerfeld, R.A. and Perla, R., 1987. The permeability of snow. Paper presented at 1987 A.G.U. Meeting, San Francisco, California, EØS, Transactions, American Geophysical Union, 68(44), 3 November, abstract, 1271

Vandenberg, A., 1986. A physical model of vertical infiltration, drain discharge and surface runoff. NHRI Paper No.25, National Hydrology Research Institute, IWD Technical Bulletin No.137, Inland Waters Directorate, Environment Canada, Ottawa, Ontario, 57 pp.

Vandenberg, A., 1987. A hybrid numerical-analytical method for the solution of partial differential equations in ground-water modelling. NHRI Paper No.36, National Hydrology Research Institute, IWD Technical Bulletin No.151, Inland Waters/Lands Directorate, Saskatoon, Saskatchewan, 16 pp.

Vandenberg, A., 1987. A foreward finite difference procedure with exponentially increasing time steps: the method of successive squaring. NHRI Paper No.37, National Hydrology Research Institute, IWD Technical Bulletin No.152, Inland Waters/Lands Directorate, Saskatoon, Saskatchewan, 14 pp.

Wasiuta, V., 1987. Feasibility study: artificial recharge in the Prairie Provinces. NHRI Contribution No.87007, Ground Water Division, National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, 86 pp.

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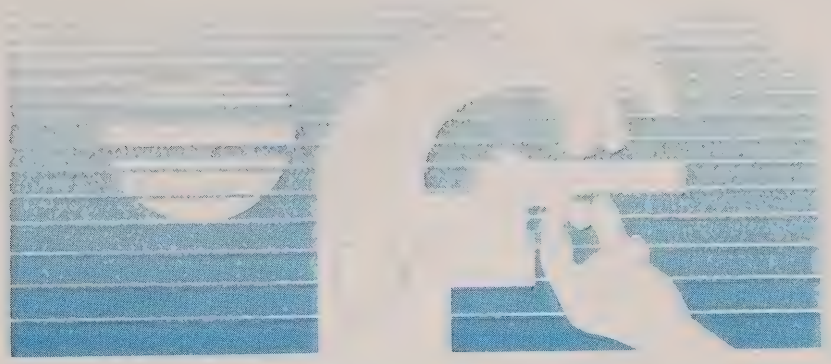
National Hydrology Research Centre



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Director's Office

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P. Richard (Secretary)
Dr V. Klemeš
Dr A.D. Stanley

As with the 1987/88 Annual Report, the 1988/89 NHRC Annual Report consolidates reports from all the operational units housed in the National Hydrology Research Centre. These include the National Hydrology Research Institute, and the tenant groups: the Hydrometeorological Research Division (HRD), Canadian Climate Centre, a Water Quality Branch (Inland Waters Directorate) laboratory, and the Saskatchewan Inspection Office of the Atmospheric Environment Service. Their reports testify to the wide range of activities that are encompassed within the Centre.

The year had many highlights. One of the most significant --and timely-- was the Prairie Drought Workshop, a scientific meeting co-sponsored by NHRI, HRD, and Agriculture Canada to address the monitoring and prediction of drought events. The workshop, attended by about 90 researchers and water resource managers, was held in October 1988, just after the summer's drought, one of the driest on the prairies in thirty years.

Another major event was the completion and commissioning of the Facility for Indoor Aquifer Testing (FIAT), which will enhance NHRI's ability to study infiltration of water into the partially saturated layer. The FIAT is a 1.5-metre high tank which will allow ground-water researchers to study infiltration in a laboratory environment without the experimental distortions common to other laboratory methods.

Ground-water scientist Dr John Ribo joined NHRI this year, and began to develop another new tool for researchers. One of the problems long associated with organic chemical analysis has been the high cost of analysing samples that may not contain even traces of contaminants. Dr Ribo is applying an analysis system called MICROTOX which provides a rapid method for screening out nil samples. The system relies on the use of bioluminescent micro-organisms sensitive to organics. Initial testing results are encouraging.

Two other new scientists, Drs Marlene Evans and Richard Robarts bring considerable expertise in the ecology of lake systems to NHRI. They and post-doctoral fellow Michael Arts have initiated new studies on the eutrophication of Saskatchewan lakes, a research area that has been neglected in the past but has great importance for water resource management in the semi-arid prairies.

Another addition to NHRI's staff was Dr Alan Stanley as planning advisor. He provided substantial leadership in the Institute's efforts to develop long-range goals and strategies.

NHRI's efforts in external communications were bolstered this year by the creation of the Scientific Information Division, under the leadership of Simon Ommanney. This new division consolidates NHRI's external information programmes, including publishing, graphics, and library services. Its efforts in external communications, and those of the Centre as a whole, were strengthened by the creation of a new Communications Officer position in Saskatoon by the department's Communications Directorate.

The Scientific Information Division is also responsible for national and international workshops and symposia, an area in which NHRI is becoming more involved. Meetings serve a vital role in advancing science and the applications of science by providing a direct outlet for the dissemination of knowledge. NHRI will hold three major meetings in the coming fiscal year, on Ground-Water Contamination, the Mackenzie Delta, and the Applications of Remote

Sensing in Hydrology. Two more major meetings scheduled for summer 1990 are already being planned: a Symposium on Northern Hydrology and a Symposium on Aquatic Ecosystems in Semi-Arid Regions.

A major new administrative initiative at NHRC has been the introduction of a paper recycling programme. If the environment is to regain its health and vitality, everyone must do his or her part to conserve resources, and Environment Canada should take a leading role as an example. NHRC's paper recycling programme provides a local non-profit agency with waste paper of all sorts -- scratch paper, bond, newsprint, and computer paper -- which they sort and sell to paper brokers for re-use.

Canadians are attaching a great deal of importance to environmental problems today. That concern in turn strengthens the resolve of NHRC to provide the expertise Canada needs to solve environmental problems.

SENIOR SCIENTIST

Dr Vít Klemeš as Senior Scientist placed his main emphasis this year on alerting the international hydrological community to hydrological problems arising from the rapidly increasing intensity and volume of man's interference with nature.

The main issues facing hydrologists in this time of environmental upheaval are the problems of unstationarity of hydrological records, nonlinearity of hydrological responses, the hydrology of large-scale continental and global systems, the changing relationship between hydrology and water resource management, the need to place stronger emphasis on geophysical, biophysical and ecological processes within hydrology and the need for changes in hydrological education to meet these new problems.

As the President of the International Association of Hydrological Sciences (IAHS), Dr Klemeš brought these problems to the attention of hydrologists by an extensive programme of lectures through Japan, China, Czechoslovakia, Spain, U.S.A., and Canada, keynote addresses at internal symposia, initiating relevant new actions through IAHS and through a workshop on Geophysical Time Series and Climate Change that he convened.

His research concentrated on non-linear problems in the hydrological response of large basins, in particular on the identification of nonlinearity from standard hydrological data.

Hydrology Division

One of the most important challenges facing Canada is its response to climatic change. There is a general concensus that the world is getting warmer: levels of radiatively-active gases such as carbon dioxide, CFCs, methane, and others are building up in the earth's atmosphere, trapping heat. Some scientists have predicted that average temperatures in the Northern Hemisphere will rise between 3 and 5 degrees Celsius during the next fifty years.

Changes of this magnitude and rapidity will have far-reaching effects on the hydrological cycle in Canada. There will be major new stresses on water availability, quality and supply. Patterns of precipitation, evaporation, and run-off are likely to change.

The Hydrology Division works to better understand the processes that will be most affected by climatic change. Many aspects of the hydrological cycle are poorly known and require investigating so we can anticipate the changes the warming might bring.

The Division covers a broad range of hydrological issues, including aspects of prairie, mountain, and northern waters. Studies in prairie hydrology deal largely with snow management, remote sensing of the snowpack, the effects of irrigation on hydrological systems, and evaporation. All are of great concern on the prairies, where rapid spring run-off and semi-arid conditions make water a scarce and precious resource.

Studies in mountain hydrology include glaciological studies that shed light on the solid phase of the water cycle and its response to climatic change. Investigations in the Coast Mountains and Rockies document changes in the amount of water held in the glacier reservoirs. Analysis of atmospheric gas trapped in glacier ice layers reveals historical climatic fluctuations dating back 300 years or more.

The fragile ecosystem of northern Canada will be seriously affected both by climatic change and economic development. Northern conditions are sufficiently different that existing, southern-based models cannot be applied there. NHRI hydrologists are investigating a variety of processes, such as river-ice break-up and ice jamming in the Liard and Mackenzie Rivers and the Delta lakes. Backwater flooding from ice jams frequently inundates Fort Simpson, N.W.T., and other northern communities. The hydrology and lakes regimes of the Mackenzie Delta are seriously affected by fluctuations in river levels. The Division is planning a major symposium in July, 1990 on northern hydrology to chart future research directions.

MICROWAVE REMOTE SENSING

Remote sensing techniques are applied to the prairie snow cover and used to detect the influence of snow structure on the absorption and reflection characteristics of electromagnetic signals. We can now compute the dielectric constants of a variety of natural and artificial snow samples with a wide range of independent variables following the successful calibration of capacitive cells for measuring water in snow. Our modified microwave model simulates emission from up to three layers and from five different surfaces of land, water, ice, and snow.

By incorporating snow cover duration in the algorithm for snowpack water equivalent we have developed a method to account for snow structure. This could improve the accuracy of snowpack measurement. We have also shown that spring run-off can be estimated from Nimbus 5 satellite microwave observations for mountains, foothills, plateaux, and plains areas in

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western Canada. The forecast accuracy rivals the conventional snow-course method using ground observations.

IRRIGATION RETURN FLOW

Most of the herbicide loss (MCPA, DICAMBA, and DICLOFOP and 2,4-D) from a typical farm field irrigated by the corrugation method, occurs during the flush of drainage water. The magnitude of the concentrations were considered to be below the LC50 limits of 10 g/L for aquatic invertebrates (USEPA 1983). In terms of the amounts applied, they were all less than 1% which is comparable to amounts observed in spring run-off from agricultural fields. The amount of nutrients lost was also low and comparable to observed 'catastrophic' rainfall run-off events from dryland agricultural fields. These observations came from a three-year study (funded under the Canada Saskatchewan Agricultural Development Agreement) to determine herbicide, nutrient and water losses.

SNOW MANAGEMENT AND SNOWMELT INFILTRATION

Compared to undisturbed, non-fractured soils, snowmelt infiltration into subsoiled and naturally-cracked soils is two to three times more in snow water equivalent. These findings and the model analysis suggest that a depth of penetration of 500 mm and a line spacing of between 0.9 and 1.3 m would allow efficient meltwater augmentation from stubble snow management practices.

PROXY CLIMATE DATA FROM ICE CORES

Analysis of data from the 103-m Mount Logan ice core is still in progress. Principal results include the discovery that, during the era of atmospheric nuclear weapons testing, nitrate levels in the snow were modulated by the nuclear detonations. Other nitrate peaks are associated with volcanic events and forest fire smoke. Background levels remain unchanged over the last 300 years indicating no anthropogenic nitrate pollution at mid-tropospheric levels in the Yukon. The same holds true for sulphate where volcanic events are primarily responsible for the elevated levels.

A snow accumulation time series was derived for the site and it shows that precipitation is modulated by ENSO (El Niño - Southern Oscillation) events, the solar cycle and some processes at lower frequencies. A significant finding is that teleconnections exist between this time series and other regions such as Japan.

GLACIOLOGICAL INVESTIGATIONS

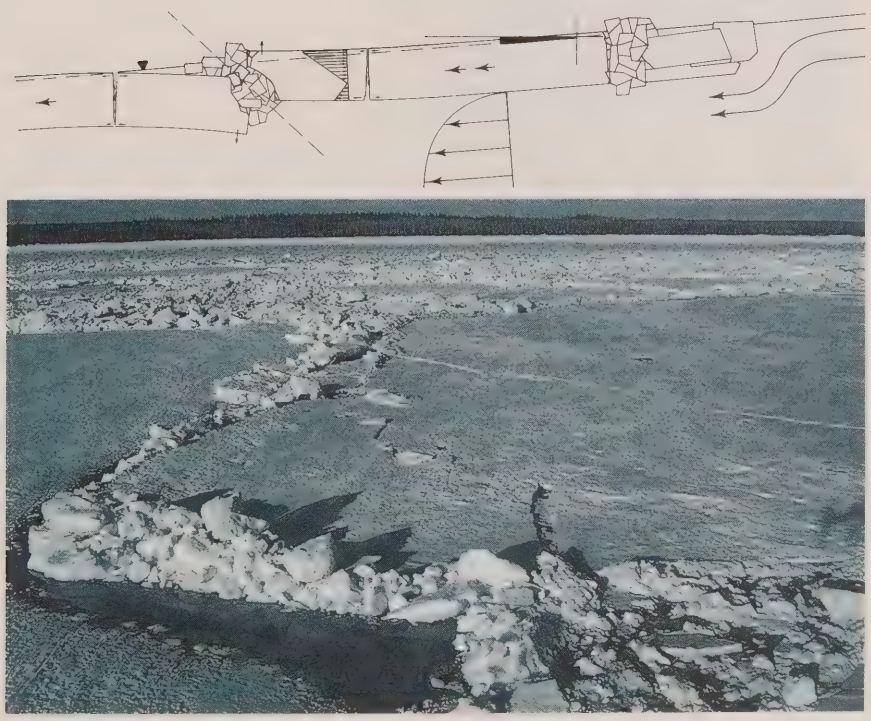
Winter- and summer-mass balance data were collected for Sentinel, Helm, and Place Glaciers. The mass-balance network was re-established on the Tiedemann and Bench Glaciers in the Homathko River basin, in collaboration with BC Hydro, and winter balance measurements were made in the second

Subsoiling to improve meltwater infiltration.

half of May. For the 1988 balance year, the specific mass change in water equivalent for the three glaciers was as follows: Sentinel Glacier +0.45 m; Place Glacier -0.97 m; and, Helm Glacier -0.15 m. Once again the former was withdrawing water from the basin while the other two glaciers were contributing additional water from storage.

INTERACTIONS IN STREAM FLOW

A study on the impact of various flow regimes on the growth rates and biological feedback in algae growth was designed for the experimental trough facility at Chase, B.C. Large (order of magnitude) differences were noted in the accumulated algal biomass for different flow regimes. These biomass differences appear to be due solely to differences in the physical flow regimes.



River ice break-up front, Mackenzie River, N.W.T.

SNOWMELT RUN-OFF IN PERMAFROST BASINS

Research was carried out on snowmelt run-off processes in both the MacKenzie Delta area and the High Arctic Islands. The work has been primarily concerned with water movement through the snow cover, meltwater infiltration into frozen soils, and the fluxes of solutes through the snow. In the MacKenzie Delta, frozen soil was found to have a large infiltration capacity so that snowmelt run-off was nearly zero. This is unusual for a permafrost environment and has important implications for the hydrology of Delta lakes. Results also show the significance of infiltration in limiting snowmelt run-off in certain circumstances, and the role played by refreezing in releasing solutes from the snowpack. This is important in understanding how pollutants are released from the snow cover.

RIVER ICE BREAK-UP ADVANCE

During melt periods, river ice can experience significant changes in strength that partly determine the severity of break-up conditions. Because of the weakness of ice during this period, *in situ* strength tests are mandatory, but relatively scarce. Strength, as measured by ultimate platen pressure, decreased by approximately 50% at a rate of 0.4 MPa/d or 0.07 - 0.08 MPa/MJ $m^{-2}d^{-1}$. The magnitude and relative importance of atmospheric (air-ice) and hydrothermal (water-ice) heat fluxes to intact and fragmented river ice covers were studied for a thermal break-up. For the Liard River, the atmospheric sources were dominant during the period of intact ice cover. Radiation was the primary heat source, but its effect was reduced by a granulation of the decaying columnar ice that increased its albedo to that of melting snow. The hydrothermal heat input, even with frazil ice entrained within the flow, was comparable to that from atmospheric sources under low melt conditions. The hydrothermal heat flux dramatically increased with the arrival of the break-up front because of a rapid rise in water

temperature and an increase in subsurface ice roughness. Higher surface roughness and lower albedo of the fragmented ice also increased the atmospheric heat fluxes, but these were small relative to the hydrothermal heat input near the leading edge of open water.

MACKENZIE DELTA HYDROLOGY

The hydrological regime of lakes in the Mackenzie Delta is controlled primarily by lake sill elevations and water levels in the Mackenzie River distributary channels. Fluctuations in regime have important effects on the water, sediment, and nutrient balance of the Delta lakes, and hence on their biological regime. Variations in the hydrological regime of the Mackenzie River could occur due to hydro-electric power development, climate change or rising sea level.

Evaporation is an important component of the water balance of Mackenzie Delta lakes. A five-year microclimatological study has shown that lake evaporation ranges from 200 to 387 mm per summer. It was always greater than summer precipitation and in some cases exceeded annual precipitation. Measurements varied from lake to lake, but differed considerably from standard maps of evaporation for northern Canada.

Since Delta lakes receive little run-off from surrounding basins, lakes which are not flooded by the Mackenzie River experience decreasing water levels. If flooding events are less frequent, the lakes will completely dry up. This has very important implications for the hydrology of lakes in the Mackenzie Delta should the river be regulated.

Aerial view of the Mackenzie Delta lakes, N.W.T.

Ground Water Division

Chemical pollutants are a major environmental concern, but their full extent and nature are not well understood, particularly on the prairies where the contamination of water resources may have serious consequences. NHRI scientists are studying the pathways of contaminants, their decay products and processes. For sustained use of water resources, we must understand the environmental relationships so that we can mitigate the effects of pollutants.

PESTICIDES IN GROUND WATER

NHRI has established several field sites across western Canada where natural conditions and known pesticide usage combine to give the highest chance of "worst-case" ground-water contamination. These sites are at Abbotsford and Osoyoos (B.C.), Taber (Alberta), and Nokomis and Outlook (Saskatchewan). Preliminary results indicate that there is no evidence for the existence of a generic pesticide/ground-water problem in the prairies, where precipitation is low, but good evidence that there may be a problem in the more moist climatic conditions of B.C. Irrigation practices do not appear to affect the incidence of contamination. However, practically nothing is known about what is happening to pesticides between the bottom of the root zone and the water table. Possible processes include adsorption and decay into other compounds by chemical and microbiological action. The relative effects of these processes will be investigated in the future.

The CWS geographic information system (SPANS) was used to produce a series of maps and a report showing the relative vulnerability of an area of southwestern Manitoba and southeastern Saskatchewan to ground-water contamination by pesticides. SPANS methodology appears to be viable and economically feasible for regional assessments of ground-water contamination by pesticides.

ORGANIC CONTAMINANTS IN GROUND WATER

NHRI took a major step this year towards overcoming the high cost of obtaining reliable, reproducible analyses of contaminants of concern (and their potential breakdown products) at very low concentration levels, by aquiring MICROTOX equipment. The MICROTOX technique is based on the response of a sensitive, bioluminescent micro-organism to low levels of chemical contamination and could be used as a low-cost, fast-screening tool. It may enable us to screen out samples with zero or insignificant levels of contamination and to reduce, by a factor of up to 10, the number of samples which require costly, and often unreliable, traditional chemical analyses by GC/MS or equivalent techniques.

An intensive programme was started to assess the capability of the MICROTOX equipment against hundreds of different chemicals, both singly and in combination. This will continue in 1989/90 using ground-water samples from field sites across the country. Conventional Gas Chromatograph and HPLC (High Performance Liquid Chromatograph) apparatus was also acquired and is being used to identify known contaminants.

ACID MINE DRAINAGE

Initial investigations at the Mount Washington Mine (British Columbia) led to new insights into the relationship of acid generation and its effects on and by the mineral assemblages present in the tailings. This offers exciting prospects for the control of acid genera-

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tion at Mount Washington and elsewhere. The new scanning electron microscope (SEM) and X-ray diffractometer (XRD) facilities at NHRI proved to be invaluable tools for this study.

PERMAFROST

Because the permafrost regions of Canada could be strongly affected by long-term changes in climate, they may be one of the more sensitive indicators of climatic change. Field investigations were confined to the discontinuous permafrost zone in the High Level area of Alberta, where the impact is expected to be severe.

Initial results seem to confirm a long-term warming trend in the discontinuous permafrost zone. Soil temperature surveys along the main north-south highway in Alberta showed consistently higher temperatures than those measured by the Geological Survey twenty years earlier. It appears that the isotherms (and hence the boundary of discontinuous permafrost) may have moved northward as much as 100 km since then. If confirmed, the permafrost/soil temperature could be used as a sensitive indicator of changes in climate.

FACILITY FOR INDOOR AQUIFER TESTING (FIAT)

This apparatus is a large experimental tank capable of fine control of water inputs and outputs and is fitted with numerous water and soil sampling ports. It was conceived as a general purpose test facility for hydrogeological and hydrogeochemical investigations on a variety of aquifer materials under highly controlled conditions. Because of its size (4.6 m high, 2.44 m in diameter), it avoids most of the edge effects and sampling disturbance problems associated with smaller experimental columns. During 1988/89 the FIAT was officially commissioned and loaded with local sand to act as the aquifer. Preliminary testing established that all significant design and operating criteria had been met successfully.

However, the preliminary tests showed that the concentration of dissolved sulphate varied considerably through the depth of the tank and that the water in the base of the tank had become anoxic. It is believed that these unexpected effects arise from microbiological action, presumably by sulphur-reducing bacteria present in the aquifer material used. The nature of the (inferred) microbiological processes in the FIAT will be investigated next year.

The first experiments conducted in the FIAT were to assess the effects of the disposal of atmospheric fluidized bed combustion (AFBC) wastes on groundwater. AFBC wastes are unusual in that they are highly exothermic on hydration (they contain a high percentage of quick-lime). There was some concern that it would be difficult to load the FIAT safely, but a series of progressively larger-scale tests provided the information required to load the AFBC wastes successfully.

DEEP-WELL DISPOSAL

Continuous, bottom-hole, pressure data from the disposal well at the Swan Hills Special Waste Facility were used to test the Alberta Research Council model. The model provided reasonable predictions of the effects of wastewater injection but demonstrated that an adequate data base on the hydrogeological parameters of a site must exist and adequate monitoring data must be available to calibrate the model prior to using it predictively. Future plans are to improve the quality of the monitoring data so as to be able to predict more confidently the effects of deep-well disposal in the oil sands/heavy oil areas of Alberta.

LONG-RANGE TRANSPORT OF AIRBORNE POLLUTANTS

Significant progress was made in clarifying the mechanisms that decrease the effect of acid precipitation on the groundwater system. Whereas previous studies concentrated on the water phase, the past year involved analysis

of drill-core material, using the Institute SEM and the newly-acquired XRD. Ground-water chemistry in the shallow zone is largely determined by precipitation chemistry. Short-term pH depressions occur in response to acid loading events. While the pH decreases, the concentration of K^+ increases. This is thought to result from more weathering of alumino-silicates, especially K-feldspar, during major precipitation events. It appears that the trace carbonates present in the shallow subsurface are insufficient to offset the acid loading events.

Collecting soil samples

LANDFILL STUDIES

This study examines the transport of contaminants in the vicinity of selected landfills in western Canada with emphasis on the special geological and other conditions characteristic of the West. A preliminary drilling programme started at the City of Regina landfill in January, 1989. A complementary drilling programme was completed at the Saskatoon landfill. Piezometers, suction lysimeters, and two larger diameter wells were installed and soil samples collected. Analysis of the samples is continuing.

Specialized, double-ring permeameters to determine the hydraulic conductivity of engineered soils using leachate and water under different hydraulic gradients were designed and constructed at NHRI. The concept for a second generation of permeameters which would permit the confining system to incrementally increase the confining stress on the barrier material has been evaluated. Biological reactor/permeameters used to study biomass accumulation in sand cushions were designed and constructed.

Aquatic Ecology Division

The Aquatic Ecology Division is primarily concerned with the effects of various types of environmental changes, such as nutrient levels, contamination, and climatic variability, on aquatic ecosystems. During the past year, activities within the division expanded with the addition of Drs Marlene Evans and Richard Robarts; future activities will include expanded studies of the trophic levels of lake systems.

LIMNOLOGICAL SURVEY

A limnological survey of 17 lakes ranging from freshwater to hypersaline was conducted during the Fall of 1988. The study will serve as the basis for a new research programme in prairie limnology. Physical and chemical parameters investigated were: temperature, oxygen, turbidity, chlorophyll and phaeophytin, total particulate carbon, nitrogen, phosphorus, dissolved phosphorus, orthophosphate, and nitrate/nitrite. Biological collections were: benthos, periphyton (algae), and zooplankton. Zooplankton samples have been scanned for species composition and abundance and will be re-examined for more detailed quantitative counts. Benthic samples were examined at a limited number of stations. Periphyton samples were sent to the Center for Great Lakes and Aquatic Sciences, Ann Arbor, Michigan, for taxonomic examination. Sediment cores were collected in Deadmoose, Waldsea, and Redberry Lakes. These cores will be sectioned and examined for fossil zooplankton, benthos, and algal remains.

Two lakes will be subject to a detailed limnological study in the fiscal year 1989/90. They are Humboldt, a weakly-saline, hypereutrophic lake, and Redberry Lake, a saline, low-productivity lake. Two other lakes, Lenore (weakly-saline and moderately productive) and Basin Lake (saline and moderately productive) will be studied on a less frequent basis. The factors affecting water quality, productivity, and energetic reserves in zooplankton in these lakes will be investigated. Redberry and Humboldt Lakes have been sampled during two winter limnological surveys while Basin and Lenore Lakes have been sampled once.

RIVER NUTRIENT STUDIES

Recent research at the NHRI Experimental Troughs Research Apparatus at Chase, B.C., has shown that algal growth in rivers is a function of phosphorus concentrations but only up to quite low levels of phosphorus enrichment. Above these levels, there is no longer any appreciable effect. This finding has major implications both for the establishment of water quality objectives for Canadian rivers and for the regulation of nutrient pollutants.

The study of nutrient impacts on the Thompson River will be in two distinct parts. The first, of 2-3 years duration, will study the river as it is now to determine the extent of downstream declines in phosphorus and the effects of these changes on algae production. The second part of the study, along the whole river, will proceed upon completion of the first part. The construction of the control research site in North Kamloops and modifications to the laboratory building are completed. Construction of the prototype facility for the lower Thompson is progressing.

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ACCUMULATION OF HEAVY METALS IN PLANKTONS AND SEDIMENTS AND BIOGEOCHEMISTRY OF HEAVY METALS

Samples of sediment and plankton have been collected from eight lakes near Flin Flon, Manitoba and prepared for study. Sediments were analysed for total mercury, methyl mercury, and sulphide, and the plankton for copper, cadmium and zinc. The chemical analysis of individual planktonic organisms and the water is complete, and the results will be interpreted in the coming year. The studies will determine the distribution of some heavy metals, assess their effects on microbial activities and investigate the different geochemical processes and environmental factors influencing the methylation and demethylation of mercury.

TOXIC CHEMICAL EFFECTS ON FRESHWATER ECOSYSTEMS

More emphasis is now being placed on realistic acute and chronic bioassay techniques to assess the effects of increasingly complex chemical burdens. The study of morphological deformities in midge larvae (Diptera:Chironomidae) is one of the techniques under development for assessing long-term chronic effects of contaminants. Operational techniques for assessing deformities in *Chironomus* and *Procladius* larvae are currently well-advanced.

Experimental Troughs Facility, Chase, B.C.

Scientific Information Division

In April 1988, the Scientific Information Division was established to provide more effective communication of the National Hydrology Research Institute's and Centre's research programmes to other scientists, to officials, and to the public, through publications, conferences, displays, and the media, etc. It also brought together the library, the snow and ice information system and the graphics section. Highlights of the past year include the publication of the 1987-1988 NHRC Annual Report of which 1250 English and 250 French copies have been widely distributed, and the publication of NHRC Notes, a comprehensive quarterly newsletter with a distribution of more than 2000 worldwide.

An important event was the arrival of Trevor Ashfield, the departmental communications officer, who has contributed significantly to the developing NHRI communications programme.

REPORTS AND PUBLICATIONS

Much of the first year was spent compiling and verifying lists of reports, and developing mailing lists for distributing information about them and our symposia and workshops. Fifty-nine reports were listed for 1987 and 93 for 1988. With the assistance of the Secretary of State, abstracts now exist for all of them in both official languages. These form the NHRI Contribution Series. In addition, there is a Contract Report Series which numbers four for 1988, a Symposium Series with its one volume being the Proceedings of the Symposium on the Interbasin Transfer of Water, and an Internal Progress Report Series which is not for general distribution. The latter series had four reports in 1987 and 10 in 1988. One other set of reports is known as NHRI Papers. These are published with the assistance of the Editorial and Publications Division of the Inland Waters Directorate in Ottawa.

For all such reports, the Scientific Information Division provides assistance ranging from the assigning of contribution numbers to substantial involvement in the editing and production of the papers themselves. A full list of the 1988 contributions can be found at the end of this annual report and includes references for 1987 omitted from the previous report.

Another series, still being developed, is that for Science Reports. This will include material of broad and general interest, often a synthesis of existing knowledge, that tends not to be covered in normal scientific literature. Work has begun on the first of these reports, a review of research on northern hydrology, that will contain contributed chapters on the hydrology of floating ice, glaciers, snow, permafrost, groundwater, regional energy and water balances and on water quality and management. By the end of the fiscal year about half the chapters had been received and editing had commenced. The second Science report, the Manual on River Ice, produced by the NRCC Subcommittee on River Ice, is also in progress.

Other work of the division included the preparation of reports on the science activities of NHRI for the Canadian Association of Geographers, the International Glaciological Society, the Canadian Geophysical Bulletin, and the Canada Water Act Annual Report, preparation of general and specific reports on the science programmes of the Institute, as well as quarterly progress reports and last year's annual report.

A report preparation and distribution room was constructed for the division and is functioning well.

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Increasing information requests kept the section extremely busy. There were almost 500 in the past year, from private industry, all levels of government, both within Canada and internationally.

Mail lists have been expanding steadily and by December 1989 a data base of at least 5,000 names will be in place from which compilations can be made for mailing the NHRC Notes, the Annual Report, conference, workshop and initial registration information.

NHRC NEWSLETTER

A major initiative this year was NHRC Notes, the Centre's newsletter. Each issue discusses some aspect of work at the Centre, progress on individual projects, staff news, and provides a current list of recent publications. One double and two single issues were prepared for 1988 and distributed to about 1,500 hydrologists in Canada and elsewhere. The response was universally positive. The feature articles to date have included an outline of the Centre and its programmes, followed by reports on research dealing with climate change and sustainable development. Unexpected demand forced the print run to be increased from 2,000 to 2,500.

CONFERENCES

The division provided assistance to NHRC staff in the planning and execution of the Prairie Drought Workshop and the Workshop on Geophysical Time Series and Climate Change, which were held at the Centre in October. Following an inadequate response to the first circular for the Rawson Conference on the Aquatic Environment, that would have been held in Saskatoon in August 1989, a new conference on Aquatic Ecosystems in Semi-Arid Regions was planned for August 1990 and information was prepared. Design work was completed and circulars for the Symposium on Ground-Water Contamination were distributed to about 2,000 people. This meeting will take place in Saskatoon in June 1989 in conjunction with a Workshop on Pesticide Contamination of Canadian Ground Waters. Draft designs and brochure text were also prepared for the Mackenzie Delta Workshop, the Symposium on Northern Hydrology and the Workshop on Remote Sensing in Hydrology. Accommodation and banquet facility bookings for some of these meetings have also been handled by the Scientific Information Division.

SNOW AND ICE INFORMATION

A number of special reports were produced during the year: a listing of recent Canadian glacier references for the Subcommittee on Glaciers; a report on the state of Canada's snow and ice resources, prepared for the IWD State-of-Environment report; and, a special, limited edition of the Glacier Atlas of Canada for distribution to a small number of national and international reference libraries.

The collection of snow and ice reprints was transferred to the library and awaits cataloguing.

LIBRARY

The library continues to provide specialized information retrieval services in support of the Centre's research programmes. New journals, particularly in the fields of climatology and aquatic ecology, have been added to the collection, bringing the current periodical subscription list to a total of 185 titles. Back issues of several of the core journals have been bought, and more will be acquired as funds become available. Scientific staff has been active in suggesting new books and reports to add to the collection, and 1,900 new documents have been catalogued since April 1988.

The Reading Room

Work on a project to have our journal and monograph holdings included in a union catalogue at the Canada Institute for Scientific and Technical Information was begun. When this project is completed in the coming year, participating libraries across Canada will have access to our collection and use of our bibliographic resources can be maximized.

In July, a full-time library technician was hired, and this has enhanced the speed and effectiveness of document delivery both to scientists within the Centre and to other researchers who have begun to use our services.

GRAPHICS

The Graphics Section is an integral part of the NHRC communication strategy and its consolidation with the Scientific Information Division has allowed an increased focus on the visual requirements of the Centre.

The Section provides management and production of graphic arts including printing, photography, drafting and illustration. Preliminary designs, layouts and detailed specifications are prepared for projects which are then contracted to the private sector or other government agencies. A consulting service is provided for planning, estimating and co-ordinating visual communication requirements for NHRC staff. Sometimes, because of deadlines, projects such as displays, reprographics or slide presentations may be completed in-house. The introduction of new computer software and laser printers has increased the graphic manager's versatility and ability to respond to such urgent requests. Future plans call for expanding this system to upgrade internal reports, the newsletter and advertising material.

The section played a vital role in designing and producing the Centre's newsletter and circulars for the many meetings being sponsored by the Centre in Saskatoon.

In addition to the successful completion of over 300 graphics projects, other responsibilities included assistance in organizing special events, participation in building utilization plans, which included the design and production of adjustable space and organization boards, and the maintenance of effective contractor/client relationships.

PUBLIC COMMUNICATIONS AND PUBLICITY

As the public's interest in environmental issues has grown, so too have the challenges for an institute such as NHRC. The public wants, and needs to know more about the work being done to understand, preserve and improve the environment. The difficulties in presenting scientific research to a non-scientific audience are daunting, particularly for a young organisation like NHRC, but several positive steps were taken in 1988-89.

In response to the growing need for NHRI and other tenant groups in the Centre to communicate the meaning of their work to the public, Environment Canada's Communication Branch established a communications officer staff position at the Centre in 1988-89. The communications officer, Trevor Ash-

field, reports to the Regional Director of Communications, Western and Northern Region, in Edmonton, and is responsible for providing communications support for the groups in the Centre, including NHRI, and for other communications tasks assigned to him by the Regional Director. These tasks include media monitoring and co-ordination of Environment Week activities, among others.

Staff assisted journalists from the Saskatoon Star-Phoenix with the preparation of a special feature on water in Saskatchewan. They also worked with SEDCO on an advertising supplement for the Star-Phoenix dealing with the various scientific activities being undertaken by tenants of the Innovation Place research park.

A new NHRI exhibit was prepared and displayed in Innovation Place in conjunction with Science Week, sponsored by SEDCO. A more substantial institute display was exhibited in Ottawa at the International Water Resources Association Meeting. The display has subsequently been used at a number of water-related meetings, particularly within Saskatchewan.

Throughout the year, staff worked with IWD HQ staff on the development of the IWD brochure and an NHRI fact sheet. This was eventually published in a package entitled Canada's Water: Canada's Future.

One of the most important undertakings in 1988-89, to increase communications with the public, was the creation of a Public Communications Strategy for NHRC. This Strategy, produced by Alan Stanley, planning advisor, in consultation with the communications officer and NHRC managers, establishes important goals and messages for the Centre's communications. It also proposes a number of "communications vehicles" to be created over the next few years to meet these goals. The thrust of the strategy is to emphasize the work of the Centre -- the science -- and environmental messages, rather than bureaucratic relationships and responsibilities.

The coming year, 1989-90, promises to be a busy one in the public communications area. New brochures, displays, and articles on NHRC work are planned. Numerous symposia and workshops scheduled by NHRC groups will create more media and public interest in the Centre. The Scientific Information Division is looking forward to the challenges these tasks will pose.

Research Support Division

The Research Support Division provides technical support to the science programmes through a Scientific Operations Section, a Computation Section and an Instrument Technology Section.

SCIENTIFIC OPERATIONS SECTION

This section is responsible for the operation of three central laboratory facilities (Chemistry, Scanning Electron Microscope and Geotechnical), logistic preparations, field support and laboratory research support. There were 14 full-time technicians and up to 12 term employees on staff this year.

The Central Chemical Laboratory provided analytical support for a variety of research projects including ground-water characterization, biochemistry of mercury, and low-level anions for paleoglaciology. A notable development in Ion Chromatography methodology during the year allows measurement of PO_4 phosphate down to 0.1 ppb using a concentrator column and suppressed conductivity detection. Contacts were established with the Saskatchewan Research Council Geochemical and Analytical Services laboratories for the exchange of analytical methods. We assisted the University of Saskatchewan Soil Science researchers with the development of their methyl mercury analysis system. NHRI hosted a Dionex Ion Chromatograph Methods Course which provides for regular interchange between a number of University and Government laboratories in Saskatoon.

The Scanning Electron Microscope provides NHRC with a state-of-the-art capability in high-resolution photomicrography, energy dispersive X-ray analysis and computerized feature analysis. S.E.M. staff contributed to many on-going research projects including: observations on the weathering effects of feldspars in sediment from the Turkey Lakes Watershed; examination of copper/arsenic precipitates from acid mine drainage; and the examination of materials used in the Facility for Indoor Aquifer Testing. An Electron Microscope Users Group was organised at the University of Saskatchewan to co-ordinate interchange of ideas and equipment.

The Geotechnical Laboratory provided particle size and gravimetric analysis in support of research on selectivity and efficiency of prototype sediment traps, characterization of aquifer materials and effects of freeze/thaw cycles on size distribution. Sample preparation for X-Ray Diffraction analysis was also provided. Field support for soil moisture measurement by neutron and gamma density meters and geotechnical sampling was contributed.

The Operations Office manages the vehicle fleet and field logistics. The former consists of 18 automobiles and light trucks, four snowmobiles, three all-terrain vehicles and a variety of boats. Logistic support was provided to research sites scattered across the western provinces and territories. Field stations at Sentinel and Place Glaciers in the Coast Mountains of British Columbia were cleaned and inventoried prior to contracting of the mass balance measurements. The station at Sunshine (Alberta) was decommissioned. Investigation and specification services were provided for new field equipment. Consultation and support was given to the hydrometric and sedimentology studies. Linkages were established with Water Survey of Canada, the Canadian Parks Service and the Canadian Wildlife Service to facilitate the exchange of technical information.

Technicians were also assigned directly to the science divisions for specific re-

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search projects. There they apply their specialized knowledge of hydrology, ground water, and aquatic biology to the collection and preparation of data. Studies have included ground-water investigations of landfill leachates in Saskatchewan, ice break-up research at the Mackenzie/Liard River confluence, N.W.T., nutrient dynamics of the South Thompson River (British Columbia), and prairie hydrology as influenced by agricultural practices in Saskatchewan and Alberta.

COMPUTATION SECTION

This section provides hardware and software support for the computer systems of the Institute through a wide range of services, including advice on personal computer problems, customized programming, system management services, custom hardware solutions, and the preparation of engineering proposals for large projects. The section also assists in Institute-wide planning of computer needs.

Several significant software projects were completed. Customized spectral series analysis of data, including transfer and conversion of data to usable format and plotting of final data output. A specialized data presentation package was written to generate image files and hardcopy output of Piper and Durov plots. A windowing user interface was developed and implemented to enhance data entry to existing programs. The Computation Section also translated mainframe source code to run on personal computers.

The major hardware project this year was the installation of the DOTS computer system. The DOTS system at NHRI consists of 24 terminals, 10 printers and 2 AT-computers networked together with a DIGITAL MicroVAX mini-computer and connected to the national DOTS network. In addition to the installation of this system, the section provides system management services.

The section also established a general-purpose computer facility which has four personal computers and assorted peripheral devices connected in a multi-user configuration. It provides all Institute personnel with access to high quality personal computing power, as well as communication and output resources.

In addition, the Computation Section provides ongoing consulting services to all members of the Institute such as communicating to off-site computer facilities; installing and configuring computers; interfacing to peripheral devices; connecting multiple computers into divisional computer networks; starting up data acquisition systems; and supporting various software packages.

INSTRUMENT TECHNOLOGY SECTION

This section liaises with the scientists and technicians and provides a centre of expertise for developing research instrumentation. It assists in the selection of specialized equipment and makes modifications to suit particular requirements. Unique in-house research instrumentation is also designed and developed to provide new capabilities for the researchers in their data acquisition, analysis and programme development.

The section includes facilities for machining, carpentry, welding, traceable calibration, electronics, and computing. Approximately 100 research jobs were supported during the year. The major projects are summarized below.

Leachate Permeameter Experimental Apparatus

A double-ring permeameter system was designed and developed for forcing sanitary landfill leachate through soil samples. All surfaces which contact the liquid are either teflon or stainless steel, to permit chemical analysis of the leachate. The system includes four independent permeameters and the ancillary equipment to support them, including: pressure regulators, gauges, sight glasses, valves, pressure transducers with associated electronics and digital readout.

Ice Core Drill System

The ice core drill control system is being modified to provide better drill control and monitoring. The system will be used on Mount Logan to obtain ice cores for palaeoclimate studies. The electronics will display and control the total operating parameters of the system including: rate of drill descent, drill position, core length and depth of hole, and will monitor generator power and the hydraulics system.

Ice-Growth Tank and Temperature Control System

An ice tank was built to produce ice for cold room lab experiments on ice strength, related to river-ice break-up and mechanics. A multi-control AC power unit controls the built-in heaters of the ice tank to permit adjustment of the temperatures and to facilitate control of ice growth.

Ice Property Test System

A system was constructed for testing the mechanical properties of ice. The system includes a compression frame, drive motor and controller, tachometer, load cell, and electronic monitoring and control panels. It allows precise control over the compression rate and load exerted on the test ice samples.

Soil Freeze Apparatus

A cylindrical heat control system was designed and built for freezing a test column of soil. This will be used for freeze-thaw and ground-water permafrost studies. Temperature control is provided by a built-in heater and thermistors for monitoring and feedback to the control unit.

Staff Services Division

The Staff Services Division provides administrative and financial services, building property management, materiel management, and an office technology system to NHRC employees with the Inland Waters Directorate. It also provides support services to the two components of the Atmospheric Environment Service located in the National Hydrology Research Centre.

ADMINISTRATIVE SERVICES SECTION

Various administrative services are provided to the Director of the National Hydrology Research Institute, including multi-year and long-term operational plans, main estimates, operational plans, and institute work plans. Staff also compile conference and overseas travel plans, chair the contract review committee, serve on the computer, health and safety, fire emergency, and the labour-management committees. They administer the Access to Information Act, prepare reports on the utilization of person-years, analyse financial data, prepare monthly reports for Institute management, coordinate all staffing and training with the Regional Personnel Office (Regina), and manage the Departmental Office Technology System (DOTS).

BUILDING AND PROPERTY MANAGEMENT SECTION

The National Hydrology Research Centre is situated on a 2.5 ha parcel of land within the Innovation Place Research Park north of the University of Saskatchewan campus in Saskatoon.

The building has a total area of 10,975 m^2, consisting of two major floor levels with a partial third floor containing mechanical equipment. A laboratory service spine running in an east-west direction bisects the building. Directly adjacent to each side of this spine are laboratory spaces which are served on the opposite side by corridors. Offices, workrooms and laboratory support spaces are located across the corridor from the lab spaces. Additional administrative space is situated at the south end of the building, while shop/warehouse space is at the north end.

A complex computer system provides a broad range of data gathering, security, and safety features as well as automatic control capabilities suitable for heating, ventilation and air conditioning monitoring, with energy management functions for the entire building.

The Building and Property Management Section is responsible for the physical operation and maintenance of the building, equipment, grounds and parking lots within the confines of the National Hydrology Research Centre. It also provides technical assistance, building modifications, installations of specialized equipment for the day-to-day operations of all tenants of the Centre.

The section is managed by a Property Manager and one assistant. All remaining individuals required for the day-to-day operations are contracted from the private sector. This involves 20 contracts/standing offers covering 32 trades and disciplines.

MATERIEL MANAGEMENT SECTION

The Materiel Management Section provides centralized procurement, inventory control of accountable assets, warehousing, management of stationery/stores, and shipping/receiving to all tenants. The section also provides mail, courier, telex, telecopier, photocopying and disposal of records services to all the occupants of the Centre.

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The central warehouse has undergone many changes and continues to change to meet the demands of the clients. A major and ongoing undertaking is the Material In Use System and the NATO Codification Project with Supply and Services Canada.

FINANCIAL SERVICES SECTION

The Financial Services Section provides computer accounting through the use of the Automated Financial Management and Accounting System (AFMAS), for NHRI and the Hydrometeorological Research Division (AES).

The section is responsible for services related to financial management with other federal, provincial and municipal government departments, central agencies and private sector suppliers concerning revenue and/or payment of accounts. It also participates in the planning process through the development of financial plans and the preparation of the main estimates.

During the past fiscal year many new spreadsheet reports were created to facilitate reporting of resources. As well as the maintenance of the on-line AFMAS system, Finance has been added to the DOTS network.

Fire emergency training for NHRC staff.

Analytical Services Division

The Water Quality Branch (WQB), Inland Waters Directorate undertakes activities such as maintaining an inventory of baseline water information, identifying pollution problems, monitoring inter-jurisdictional waters and determining compliance with water-quality objectives. WQB has offices in each of the five regional offices of the Inland Waters Directorate across Canada.

The Analytical Services Division of WQB for the Western and Northern Region is located at the National Hydrology Research Centre in Saskatoon. The Division, which provides nutrient analysis of water in support of WQB survey and monitoring programmes, reports to the regional headquarters in Regina. The Division's staff maintains a 280 m^2 laboratory, a computer terminal room, a shipping and receiving area and four offices. Division computer terminals are linked to the regional WQB VAX 750 computer in Regina.

In addition to its main role of nutrient analysis, the Division provides assistance to Federal-Provincial cost-shared water-quality monitoring programmes in the Western and Northern Region. It also provides analytical work for other agencies on a cost-recovery basis, under formal or co-operative arrangements. The Division laboratory is capable of measuring levels of pH, alkalinity, physical parameters, boron, chlorophyll-a, cyanide, and phenolics.

Staff consists of three chemists and three laboratory technicians. Employees hired through contracting-in arrangements provide most of the shipping/receiving and sample bottle-washing services, and contribute to some of the analytical work.

The group has been able to analyse a larger number of samples through increased automation, without sacrificing data quality. High-speed continuous flow analyses (TRAACS system) have been aquired to improve both the quality and productivity of analyses. The TRAACS system is capable of analysing samples at a rate of 100 an hour, and is being used for routine analysis of phosphates. A second system will be used for ammonia and nitrate/nitrite analyses. In 1988-89, the laboratory received 3,391 samples and performed 47,027 tests.

Compositing of Organic Extracts

Monthly sample extracts were composited over a period of several months and the composite subsequently analysed for target compounds, which included organochlorine pesticides and PCBs, acidic and neutral herbicides. This was done with a view to reducing the operational costs for routine monitoring of the target toxic organic chemicals while still maximizing useful information on the presence and abundance of these compounds in an aquatic environment. The extractions were performed in the Saskatoon laboratory and the analyses at the National Water Quality Laboratory. Results indicate that this concept is a viable alternative to monthly analysis, although the protocol will have to be further developed before it is implemented on a routine basis.

Broad Spectrum Analysis of Trace Organic Chemicals

This method analyses for the largest possible number of chemicals in a sample, and thus provides maximum information on its organic composition. Its usefulness is based on the ability to observe changes in water quality data from differences between chromatograms. It is an alternative to the target compound analysis.

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Atmospheric Environment Service
Service de l'environnement atmosphérique
Weather Radar Station
Station de radar météorologique
Canada

Hydrometeorological Research Division

Canadian Climate Centre

The Hydrometeorological Research Division is a component of the Applications Branch of the Canadian Climate Centre. Its mandate is to provide a national programme of basic and applied hydrometeorological research for western and northern Canada. The eight full-time staff of the division were very active in 1988-89 and pursued their research interests with vigour.

Division scientists and meteorologists authored or co-authored a number of reports, supervised the work of contract researchers, and made numerous presentations at scientific conferences. Three conference papers were given as a result of invitations which staff received from conference organizers. Division staff was also invited to chair three sessions at the 6th International Water Resources Association (IWRA) Congress held in Ottawa in the summer of 1988 and Dr Geoff Kite was asked to participate as a panel member in the workshop on Geophysical Time Series held by NHRI in Saskatoon.

Division Chief Rick Lawford participated in the University of Saskatchewan public lecture series on global change, presenting one lecture, "The Global Water Cycle in Transition" with Dr T. Milne Dick, NHRI, and another on his own entitled, "What can we do about Global Change and its Impacts on the Water Cycle?" He also presented a review of drought conditions on the Canadian prairies at the October seminar on the 1988 drought, held in Washington, D.C.

The Division also contributed to the Royal Society's initiative on global change. Both Les Welsh and Rick Lawford participated in meetings to develop a prairie initiative related to global change.

During the year, the Division strengthened its close working relationship with the National Hydrology Research Institute by launching a number of joint initiatives. It also received financial support through agreements with a number of other Environment Canada groups such as the Central Region (AES), the Canadian Wildlife Service, the Ontario Region (Conservation and Protection), and IWD's Water Planning and Management Branch. A number of projects involving Agriculture Canada, the Saskatchewan Water Corporation, and other agencies, were initiated. Six scientific contracts were let to researchers with other organisations, including a major initiative with McGill University to develop and install a radar data processing system. The Division contributed ideas, proposals and support to the climate change component of the International Geosphere-Biosphere Programme (IGBP) global change programme and to several proposals by universities for Centres of Excellence. Division staff also supported the university community by giving a course with the University of Saskatchewan Geography Department and supervising two graduate students.

The Division dealt with a total of 233 sector/service information requests in the fiscal year 1988/89, including such diverse activities as support to educational institutions through consultations on student projects, public talks on the climatic change issue, and support to research projects at the University of Saskatchewan. A climatic information display board was maintained for National Hydrology Research Centre personnel and visitors.

Research initiatives in 1988/89 fell into five categories. The four principal areas included hydroclimatology, remote sensing and hydrometeorological models, prairie hydrometeorological processes and quantitative precipitation monitoring and forecasting. The fifth, arctic and alpine hydrometeorology received less emphasis due to resource constraints.

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PRAIRIE DROUGHT

Prairie Drought Workshop

One of the highlights of the Division's activities was an international workshop dealing with drought phenomena. Eighty-eight scientists and managers from Canada and the United States participated in the Prairie Drought Workshop held at the National Hydrology Research Centre in Saskatoon, Saskatchewan, October 11 to 13, 1988. It was sponsored jointly by the Prairie Farm Rehabilitation Administration (PFRA) of Agriculture Canada, and NHRI and the Canadian Climate Centre (CCC), both of Environment Canada. The Hydroclimatology Section, under the leadership of Les Welsh, was responsible for the organisation of the Workshop.

Four sessions addressed Drought Driving Forces; Drought Monitoring, Detection and Early Warning; Drought Prediction; and Drought in the Future. Each was introduced by a keynote speaker and one or two invited speakers. The participants divided into working groups to discuss issues arising from every session topic and to formulate recommendations. There were also a number of Poster Papers. Proceedings of the Prairie Drought Workshop are now available.

Characteristics of the 1988 drought

The Division initiated a multi-agency study, to be carried out by the Saskatchewan Research Council and the University of Manitoba, on the economic and environmental effects of the drought. This study, which has a broad base of funding support, is expected to provide hard statistical data on the extent of the 1988 drought and to provide insight into the most appropriate models for estimating the effects of drought.

Drought Prediction

The agricultural community is very concerned about future droughts, dry conditions and the forecasters' ability to predict them. A review of drought prediction methodologies was carried out under contract by Prof. E. Ripley of the University of Saskatchewan. There appear to be a number of factors which influence a drought event including sea-surface temperatures, snow cover and soil moisture. However, on a seasonal time scale, he concluded that success in drought prediction will likely result from the development of a physical/statistical model or through the application of teleconnections. Some of these ideas are being explored in a joint initiative between the Division and the University of Saskatchewan Geography Department.

Work by Dr John Knox and Rick Lawford, on the relationship between anomalies in the atmospheric circulation patterns and wet and dry months on the Canadian prairies, may provide a stronger basis for understanding the meteorological drought phenomenon. Their study, which focused on the growing season, indicated that well-defined anomaly patterns are associated with wet and dry months. During dry months an area of anomalously high heights is generally found to the west of the dry area.

Drought Bibliographic Database

Don Bauer led this project, consolidating the more than 3,000 references to drought in the scientific literature. The references, including many with annotations, were incorporated in a newly-developed microcomputer bibliographic data base which is available for reference at the Centre.

CLIMATIC CHANGE AND VARIABILITY

Climatic Warming Scenarios and Water Resources in the Saskatchewan River Sub-basin

This is a co-operative project with Dr S.J. Cohen of the Arctic Meteorology Section (CCC). Several general circulation model scenarios of climates warmed by a doubling of carbon

dioxide concentration were used as input to a Thornthwaite water-balance model in order to calculate resulting streamflow at The Pas on the Saskatchewan River.

A wide range of mean streamflow scenarios resulted, with an extreme decrease of 70% on one hand to a 40% increase on the other. Proper incorporation of reservoir evaporation and projected irrigation water-use was important in such a calculation. Also, normal precipitation, especially in the Rocky Mountain portion of the watershed, must be much more accurately known in order to validate models for the current climate prior to extrapolation to a warmed climate.

Variability of Hydrometeorological Parameters

Dr Geoff Kite undertook a study of the secular variations in precipitation, river run-off and lake levels using a time-series analysis programme which he developed. The study determines if time-series analysis techniques can be used to detect a climatic change signal in these parameters. The results indicate that these signals cannot be seen in precipitation or river run-off trends. Furthermore, trends in lake levels which are statistically significant likely arise from factors such as isostatic rebound rather than climatic change.

Climatic change and northern hydrology

Rick Lawford presented an invited review paper outlining the possible influences of climatic change on the hydrological cycle in the north, in Whitehorse. Areas where an altered climate could have a significant impact on northern hydrological patterns arise from effects on glaciers, snow cover, river basin characteristics, permafrost, river ice break-up, sea ice cover, and northern ecology.

Winter Temperatures

A study of temperature cycles with particular emphasis on the winter period has been undertaken by Dr Geoff Strong. This study is intended to confirm 15- to 20-day cycles found in earlier studies, and to add additional stations to the analysis in order to examine any west-east or north-south progressions in more detail. Most of the analysis has been completed, and some additional features with respect to urban warming and climate warming have been noted.

REMOTE SENSING AND DISTRIBUTED HYDROLOGICAL MODELS

The value of remote sensing has been documented extensively and, in some sectors, remote-sensing data are now used operationally. However, the benefits of using this type of information to derive hydrometeorological fields such as snow and cloud cover for hydrological models have not been fully documented.

The remote-sensing project being undertaken by Dr Geoff Kite has three objectives: to investigate the utility of satellite data in a hydrological model in different physiographic and climatic zones; to use a hydrological model with satellite data as a test-bed for physically-based model components; and, at a later stage, to develop a land-phase component for global circulation models. The database needed to combine meteorological, hydrometric, physiographic, land-use and satellite data has been completed and data have been entered for the Kootenay and Souris basins for 1988.

Two hydrometeorological models will be used. A simple lumped model, SLURP, has been calibrated on both basins. This model checks input data and acts as a base-case for the other model. The second model is Hydrotel, a distributed model being developed by l'Université du Québec (INRS-Eau).

The SLURP model has attracted the interest of other agencies. Copies of SLURP have been requested by IWD, Canadian Forestry Service, US Soil Conservation Service and Lavalin Engineering Inc. A co-operative study with Dr

Terry Prowse, NHRI, has been initiated to apply SLURP to permafrost basins. These applications will assist in evaluating the performance of the model and increasing its versatility.

HYDROMETEOROLOGICAL PROCESSES

Evaporation is recognized as a very important process on the prairies, especially during the growing season when the rate of evaporation over open water exceeds precipitation by factors of two to six. Its importance takes on additional meaning during periods of drought, or high temperatures, so it requires special consideration in the context of climate warming.

The Prairie Evaporation Study

In spite of the importance of evaporation on the prairies, areal evaporation from open water cannot be measured directly, nor estimated accurately. Monthly values of reservoir evaporation, for example, whether estimated from evaporation pan data, from Meyer's formula, the Morton technique, or other semi-empirical methods, can be in error by as much as 50%. Furthermore, there are presently no Canadian data sets available which are adequate for a scientifically-sound evaluation of the accuracy of such techniques. The Prairie Provinces Water Board (PPWB) Committee on Hydrology (COH) requested that comparative evaluations between the different evaporation models be made. The Prairie Evaporation Study, a project of the Division and NHRI, was initiated as a result. Dr. Geoff Strong, in collaboration with NHRI, has prepared a proposal for a six-week study, outlining the various research options.

A Review of Open-Water Evaporation

The problem of translating point measurements to areal estimates of open-water evaporation is quite complex, and estimates of uncertainty in even a monthly average value is of the order of 50%. To obtain a better understanding of the problems of evaporation estimates, a study which uses existing climatological data to compare Meyer and Morton estimates of evaporation with evaporation-pan data was completed. The study, available as an NHRI report, confirms the inaccuracy of the current techniques used to estimate areal evaporation from water bodies, and emphasizes the need for measurement standards to fine-tune these techniques. A review paper being prepared for the Associate Committee on Hydrology will summarize the various techniques used to obtain open-water estimates, discuss the data uncertainties, and recommend procedures to improve the estimates.

Prairie Climate/Wetlands Study

Prairie wetlands, which provide vital habitat for migratory waterfowl, are very sensitive to climate fluctuations. With the possibility of future climate warming, it is important for wildlife managers to ascertain the changes which may occur in waterfowl habitats. The Division, with funding and technical support from the National Hydrol-

St. Denis research site

ogy Research Institute, the Canadian Wildlife Service, Ducks Unlimited and the Canadian Climate Centre, has contracted a study on wetlands with McMaster University. The study will improve our understanding of the hydrological and hydrometeorological processes of a prairie wetland as part of the assessment of the susceptibility of western wetlands to climatic variability.

The field site is in the Canadian Wildlife Service's St. Denis National Wildlife area, 40 km east of Saskatoon. The basin is representative of most prairie wetlands, consisting of five land-cover types: grassland, wheat field, woodland, wetland and a water body. An extensive observational programme will begin in the spring of 1989. Analysis of the data acquired during the field seasons will lead to a hydrological model to assess the changes in prairie wetlands in response to present and future climates.

QUANTITATIVE PRECIPITATION MONITORING AND FORECASTING

Radar Hydrometeorology

The Division, in co-operation with the Central Region of Weather Services Directorate, is upgrading the Elbow, Saskatchewan weather radar to fully digital processing. This upgrade will be completed in the summer of 1989. It will then be operated in an automated volume-scanning mode with a 10-minute cycle. All radar precipitation data will be archived on tape at the main processing unit in the National Hydrology Research Centre. Processed radar data will be displayed at the Saskatoon Weather Office and will be available for call-up by other users, such as the Prairie Weather Centre. Joe Eley is managing the acquisition and implementation stages of the system.

The Division will use the digital archive for research in prairie hydrometeorology. This will include studies of the climatology of convective precipitation and heavy precipitation events. Development work will be carried out to make radar-derived precipitation data more accessible to users on the prairies, such as providing radar-derived precipitation data to the Irrigation Branch of the Saskatchewan Water Corporation.

Irrigation Scheduling Information System

The Division has been contracted by the Irrigation Development Centre and the Saskatchewan Water Corporation to develop an irrigation scheduling information system for use by the Corporation at Outlook. The system will help make irrigation more efficient and profitable by allowing farmers to water their crops with more precision. The Division contracted the University of Saskatchewan to review a number of existing soil moisture models and test the most promising models on data acquired by the University's field studies in 1988 on an irrigated farm near Birsay, Saskatchewan. A model was selected and modified slightly to improve its performance. Joe Eley has transferred the technology to the Saskatchewan Water Corporation.

ARCTIC AND ALPINE HYDROMETEOROLOGY

Three studies have been undertaken in this area. The first is a review of the needs for research in arctic hydrometeorology based on interviews with a number of experts in arctic hydrology and meteorology and on interviews with users of hydrometeorological information. A second study in alpine hydrometeorology assesses the hydrometeorology of the western Cordillera at several scales. A third study, initiated in the late winter of 1988 under contract to the University of British Columbia, will review our current ability to determine the possible influences of climatic change on the hydrology, coastal currents and fisheries of British Columbia.

Saskatchewan Inspection Office

AES Central Region

The Saskatchewan Inspection Office, part of the Atmospheric Environment Service (Central Region), is responsible for the installation, maintenance, and regular inspection of weather stations in Saskatchewan and of four sites in the High Arctic Islands of the Northwest Territories. The office is staffed by three meteorological inspectors, two electronic technicians and a summer student.

The area served by the Office comprises 23 mainline weather stations, 10 automatic weather stations, and approximately 240 volunteer weather observers, situated in small towns and on farms around the province. This past year the staff logged in excess of 130,000 km by road and 75,000 km by air, getting to and from the many locations visited.

Staff made 50 inspections to the mainline and automatic stations to ensure continuity and completeness of data. The climate network received 135 visits. Some sites were selected for upgrading of facilities and others received completely new facilities.

About one week is required for a full inspection of the equipment and programmes at a mainline station, which may be operated by AES, Transport Canada or by contract. Inspections of automatic stations are shorter, usually only a day, but more frequent, twice a year. Nine of the stations are operated in total or in part by contract weather observers so another facet of the Office's work is their training.

The electronic technicians share responsibility for the maintenance of the electronics at seven automatic weather stations, the weather radar equipment at Elbow, Sask., and the weather radio equipment at the Saskatoon airport. This involves ensuring output data are complete and equipment is in order. Over 50 scheduled and emergency visits were made to the automatic stations. The radar site at Elbow is inspected biweekly and on an emergency basis as required. One technician spent four months at Resolute Bay, N.W.T., as part of the Office's responsibility for weather stations in the High Arctic.

Other projects during this fiscal year included the installation of Campbell Scientific "Automatic" weather equipment near Reindeer Lake at Southend, Sask., the complete relocation of the mainline meteorological station on Wollaston Lake at Collins Bay, Sask. and the installation of meteorological equipment in the new Transport Canada air terminal building at the La Ronge airport. Eleven new "tilt down" towers for wind equipment were installed at various airports in Saskatchewan. Campbell Scientific data loggers were installed at two sites in Saskatchewan and four sites in the High Arctic as part of the upgrading of the "Solar Radiation" data gathering network.

AES maintains a Canadian Air and Precipitation Monitoring Network (CAPMoN) station at Cree Lake, Sask., which requires four visits annually by inspection staff. The station was improved with the addition of a computerized data logger for the air-sampling system. Inspections were also carried out at 135 of the about 240 volunteer weather observing stations throughout Saskatchewan. Eight of the volunteer observers were presented with awards during Environment Week in recognition of excellence and long service.

Staff are often involved in liaison with other agencies whose activities have an impact on weather stations. This year, staff dealt with SaskTel, which was plowing in cable near the Eastend weather station, and the City of Estevan, during the development and construction of their new airport facilities.

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Staff also responded to requests for replacement equipment and weather information. As well, the Saskatchewan Inspection Office is involved in the development of weather stations, from site inspection, blueprint development, contractor supervision, cable trenching, equipment installation, to the approval of a completed facility.

Publications and Reports

Publications and Reports of the National Hydrology Research Institute

[CS = Contributions of the National Hydrology Research Institute]

[CR = Contract Reports completed for the National Hydrology Research Institute]

Bigras, S.C., 1988. Hydrochemical aspects of lakes and channels in the Mackenzie Delta, N.W.T. [CS-88019] - 40 pp.

Bigras, S.C., 1988. Ice jamming characteristics of the Mackenzie Delta, N.W.T. Proceedings of the 45th Annual Eastern Snow Conference, 8-9 June 1988, Lake Placid, New York, 129-139

Bothwell, M., 1988. Growth rate responses of lotic periphytic diatoms to experimental phosphorus enrichment: the influence of temperature and light. Canadian Journal of Fisheries and Aquatic Sciences, 45(2), 261-270

Brown, T., 1988. Soil moisture plotting program. Contract No.KW504-7-1419, Division of Hydrology, Department of Agricultural Engineering, University of Saskatchewan, Saskatoon, Saskatchewan. [CR-88003] - 24 pp.

Chew, H.[A.M.], L.M. Johnston, D. Craig and K. Inch, 1988. Aluminum contamination of groundwater: Spring melt in Chalk River and Turkey Lakes watersheds - preliminary results. Canadian Journal of Fisheries and Aquatic Sciences, Vol.45, Supplement No.1, 66-71

Craig, D. and L.M. Johnston, 1988. Acidification of shallow ground waters during the spring melt period. Nordic Hydrology, 19(2), 89-98

Craig, D. and L.M. Johnston, 1988. Acid precipitation and groundwater chemistry at the Turkey Lakes Watershed. Canadian Journal of Fisheries and Aquatic Sciences, Vol.45, Supplement No.1, 59-65

Demuth, M.N., G. Holdsworth and R. Brancker, 1988. Shallow ice borehole logger and deployment system. [CS-88018] - 20 pp.

Demuth, M.N. and T.D. Prowse, 1988. *In situ* testing of river-ice strength using a hydraulic borehole jack. Proceedings of the 45th Annual Eastern Snow Conference, 8-9 June 1988, Lake Placid, New York, 181-185

Dick, T.M., 1988. Scientific research programme: National Hydrology Research Institute. [CS-88038] - 39 pp.

Dozier, J., R.E. Davis and R. Perla, 1987. On the objective analysis of snow microstructure. Avalanche Formation, Movement and Effects, B. Salm and H. Gubler (Editors), IAHS Publication No.162, International Association of Hydrological Sciences, I.U.G.G., 49-59

Fogarasi, S. and G. Holdsworth, 1988. An investigation of large-scale upper-air flow as a means of explaining the teleconnections between long-term glacier mass balance variations on Mount Logan and long-range spatially averaged precipitation variations in the Prairie/Steppe regions of North America and Eurasia (U.S.S.R.). [CS-88012] - 31 pp.

Holdsworth, G., 1988. Iceberg. The Canadian Encyclopaedia, Second Edition, Volume II: Edu - Min, J.H. Marsh (Editor), Hurtig Publishers, Edmonton, Alberta, 1038

Holdsworth, G., 1988. Logan, Mount. The Canadian Encyclopaedia, Second Edition, Volume II: Edu - Min, J.H. Marsh (Editor), Hurtig Publishers, Edmonton, Alberta, 1238

Holdsworth, G., 1988. Mt. Logan glaciology, 1986. The Canadian Alpine Journal, Vol.71, 56-57

Holdsworth, G., 1988. Mt. Steele glaciology, 1987. The Canadian Alpine Journal, Vol.71, 57

Holdsworth, G. and W. Blake, Jr, 1988. Obituaries: John Hainsworth Mercer (1922-1987). Arctic, 41(2), June, 164-165

Holdsworth, G., S. Fogarasi and H.R. Krouse, 1988. Atmospheric structural and climatological implications of stable isotope data from Mount Logan, Yukon Territory, Canada. [CS-88040] - 27 pp.

Holdsworth, G., S. Fogarasi, H.R. Krouse and M. Nosal, 1988. Climatic indicators in an ice core from the Yukon. Abstracts, 5th Workshop on Climate Variability of the Eastern North Pacific and Western North America, 20-24 March 1988, Pacific Grove, California, 5

Holdsworth, G., H.R. Krouse and E. Peake, 1988. Trace-acid content of shallow snow and ice cores from mountain sites in western Canada. Proceedings of the Symposium on Ice-Core Analysis, 30 March - 3 April 1987, University of Bern, Switzerland, Annals of Glaciology, Vol. 10, 57-62

Jackson, T.A., 1988. Accumulation of mercury by plankton and benthic invertebrates in riverine lakes of northern Manitoba (Canada): importance of regionally and seasonally varying environmental factors. Canadian Journal of Fisheries and Aquatic Sciences, 45(10), October, 1744-1757

Jackson, T.A., 1988. Effects of clay minerals, hydrated oxides, and humic matter on microbial methylation and demethylation of mercury in freshwater environments. Preprint of Papers presented at 3rd Chemical Congress of North America, 28(1), Symposium on Organometallics in the Environment, 5-10 June 1988, Toronto, Ontario, Division of Environmental Chemistry, American Chemical Society, 589-594

Jackson, T.A., 1988. The mercury problem in recently formed reservoirs of northern Manitoba (Canada): effects of impoundment and other factors on the production of methyl mercury by microorganisms in sediments. Canadian Journal of Fisheries and Aquatic Sciences, 45(1), January, 97-121

Jackson, T.A., 1988. Speciation, availability, and bio-accumulation of mercury in lakes. Abstracts of the Conference, 9th Annual Meeting, Society of Environmental Toxicology and Chemistry (SETAC), 13-17 November 1988, Arlington, Virginia, 54

Johnston, L.[M.], 1988. Session 1. Water quality monitoring activities in the North - National Hydrology Research Institute - discussion. Northern Water Quality Monitoring, Proceedings of the Technology Transfer Workshop, 4-7 May 1987, Yellowknife, N.W.T., IWD Technical Workshop Series No.7, Inland Waters Directorate, Environment Canada, Ottawa, Ontario, 74-80

Klemeš, V., 1987. Empirical and causal models in hydrologic reliability analysis. Engineering Reliability and Risk in Water Resources, L. Duckstein and E.J. Plate (Editors), Martinus Nijhoff Publishers, Dordrecht/Boston/Lancaster, 391-403

Klemeš, V., 1987. Hydrological and engineering relevance of flood frequency analysis. Hydrologic Frequency Modeling, V.P. Singh (Editor), Proceedings of the International Symposium on Flood Frequency and Risk Analyses, 14-17 May 1986, Louisiana State University, Baton Rouge, U.S.A., D. Reidel Publishing Company, Dordrecht, 1-18

Klemeš, V., 1987. One hundred years of applied storage reservoir theory. Water Resources Management, 1(3), 159-175

Klemeš, V., 1988. Effects of storage mechanisms on geophysical time series. Proceedings of the 35th Annual Meeting, Pacific Northwest Region, American Geophysical Union, 28-30 September 1988, Victoria, British Columbia, Abstract, 16

Klemeš, V., 1988. A hydrological perspective. Journal of Hydrology, 100(1-3), 30 July, 3-28

Klemeš, V., 1988. Hydrology and water resource management: the burden of common roots. Water for World Development, Vol.I - Summary, Special Sessions, Training and Education, Proceedings, 6th IWRA World Congress on Water Resources, 29 May - 3 June 1988, Ottawa, Ontario, International Water Resources Association, 368-376

Klemeš, V., 1988. (One hundred years of applied storage reservoir theory). In Chinese, Proceedings of the Symposium on Methodology in Hydrology, R. Liang, S. Cong and F. Bing (Editors), 2-5 April 1988, Nanjing, China, 118-122

Klemeš, V. and I. Klemeš, 1988. Cycles in finite samples and cumulative processes of higher orders. Water Resources Research, 24(1), January, 93-104

Lam, D.C.L., A.G. Bobba, D.S. Jeffries and D. Craig, 1988. Modelling stream chemistry for the Turkey Lakes Watershed: comparison with 1981-84 data. Canadian Journal of Fisheries and Aquatic Sciences, Vol.45, Supplement No.1, 72-80

Landine, P.G., R.J. Granger and D.M. Gray, 1988. Evaluation of snowmelt models for application in permafrost environments. Contract No.KW504-7-1554, Division of Hydrology, College of Engineering, University of Saskatchewan. [CR-88001] - 54 pp.

Letréguilly, A., 1988. Relation between the mass balance of western Canadian mountain glaciers and meteorological data. Journal of Glaciology, 34(116), 11-18

Maathuis, H., V. Wasiuta, W. Nicholaichuk and R. Grover, 1988. Study of herbicides in shallow groundwater beneath three irrigated sites in Outlook Irrigation District, Saskatchewan: results of 1987 field investigations. [CS-88049] 94 pp.

Marsh, P., 1988. Flow fingers and ice columns in a cold snow cover. Proceedings, 56th Annual Western Snow Conference, 18-20 April 1988, Kalispell, Montana, 105-112

Marsh, P., 1988. Soil infiltration and snow-melt run-off in the Mackenzie Delta, N.W.T. Proceedings, 5th International Conference on Permafrost, K. Senneset (Editor), 2-5 August 1988, Trondheim, Norway, Tapir Publishers, Vol.1, 618-621

Marsh, P. and S.C. Bigras, 1988. Evaporation from Mackenzie Delta Lakes, N.W.T., Canada. Arctic and Alpine Research, 20(2), May, 220-229

Marsh, P. and S.[C.] Bigras, 1988. Lake hydrology studies in the Mackenzie Delta, N.W.T. Proceedings, Canadian Hydrology Symposium No.17 - 1988, Canadian Research Basins: Successes, Failures and Future, CHS-88-SCH, 9-11 May 1988, Banff, Alberta, Associate Committee on Hydrology, National Research Council of Canada (NRCC No.30416), 255-263

Marsh, P. and M. Ferguson, 1988. Sediment regime of lakes in the Mackenzie Delta: Report on NOGAP Project No.C.11A. [CS-88016] - 70 pp.

Marsh, P. and M. Hey, 1988. Mackenzie River water levels and the flooding of Delta lakes. [CS-88013] - 135 pp.

Martinerie, P., D. Raynaud, D. Mazaudier, A.J. Gow, G. Holdsworth, V.Ya. Lipenkov and N.W. Young, 1988. The relationship between total gas content of polar ice, atmospheric pressure and surface elevation. Proceedings, 4th International Symposium on Antarctic Glaciology, A.J. Gow (Editor), 7-11 September 1987, Bremerhaven, Federal Republic of Germany, Annals of Glaciology, Vol.11, abstract, 203

McConkey, B. and W. Nicholaichuk, 1988. Wheat farming with grass barriers. Weekly Newsletter No.2, January 13, Agriculture Canada Research Station, Swift Current, Saskatchewan, 1 pp.

McConkey, B., W. Nicholaichuk and J.D. Beaton, 1988. Grass barriers for wheat production in southwest Saskatchewan. Proceedings, Soils and Crops Workshop, 18-19 February 1988, University of Saskatchewan, Saskatoon, Saskatchewan, Advisory Council on Soils and Agronomy, Vol.1, 380-400

McConkey, B., D. Ulrich, W. Nicholaichuk and H. Steppuhn, 1988. Subsoiling to improve soil structure for enhanced snowmelt infiltration and better crop growth. Paper presented at Canadian Society of Agricultural Engineering Annual Meeting, 23 August 1988, Calgary, Alberta, 31st Canadian Agricultural Engineering Conference, Agricultural Institute of Canada, abstract, 1 pp.

McNaughton, D., 1988. Session 3. General - Ground-water quality issues in northern Canada. Northern Water Quality Monitoring,Proceedings, Technology Transfer Workshop, 4-7 May 1987, Yellowknife, N.W.T., IWD Technical Workshop Series No.7, Inland Waters Directorate, Ottawa, Ontario, abstract, 110

McNaughton, D.C., 1988. Pesticides and ground water quality; a field study in western Canada. Agricultural Chemicals and the Environment, Proceedings of Meeting, Manitoba Institute of Agrologists, Western Branch, 24 February 988, Brandon, Manitoba, 13 pp.

Mokievsky-Zubok, O., 1988. Glacier mass balance for 1987 on Sentinel, Helm and Place Glaciers, British Columbia. [CS-88009] - 17 pp.

Moore, R.D. and T.D. Prowse, 1988. Snow hydrology of the Waimakariri Catchment, South Island, New Zealand. Journal of Hydrology (N.Z.), 27(1), 44-68

Nicholaichuk, W., 1988. Drought monitoring, detection & early warning - summary. Proceedings of the Prairie Drought Workshop, Saskatoon, Saskatchewan, 11-13 October 1988, D.J. Bauer (Editor), NHRI Symposium No.2, National Hydrology Research Centre, Saskatoon, Saskatchewan, 125-126

Nicholaichuk, W., 1988. Education and training in the Third World. Water for World Development, Vol.I - Summary, Special Sessions, Training and Education, Proceedings, 6th IWRA World Congress on Water Resources, 29 May - 3 June 1988, Ottawa, Ontario, International Water Resources Association, 452-459

Nicholaichuk, W., 1988. Soil and water conservation on the farm. Proceedings, Alberta Soil and Crops Workshop, 22-23 February 1988, Lethbridge, Alberta, Jasper Printing, Edmonton, 15-31

Nicholaichuk, W., C. Chang, S. Fogarasi, F. Davies, G. Beke and J. Whiting, 1988. Areal evapotranspiration over different agricultural surfaces using the Complementary Relationship Areal Evapotranspiration Model. Paper presented at Canadian Society of Agrometeorology Annual Meeting, 23 August 1988, Calgary, Alberta, 31st Canadian Agricultural Engineering Conference, Agricultural Institute of Canada, abstract, 2 pp.

Nicholaichuk, W., S. Fogarasi, C. Chang, G. Beke, F. Davies, F. Morton and J. Whiting, 1988. Field testing the complementary relationship areal evapotranspiration (CRAE) model. Evaporation and Evapotranspiration Processes, F.J. Eley (Editor), Proceedings of Workshop, 20-21 May 1987, Saskatoon, Saskatchewan, Canadian Climate Centre Report No.88-2, unpublished manuscript, Atmospheric Environment Service, National Hydrology Research Centre, Saskatoon, Saskatchewan, 63-65

Nicholaichuk, W., D.M. Gray and B. McConkey, 1988. Interim progress report: Snow management and meltwater enhancement. Project 3.2-3, Canada/Saskatchewan Economic & Regional Development Assistance (ERDA) Fund: October, 1988. [CS-88088] - 7 pp.

Nicholaichuk, W., D.M. Gray and B. McConkey, 1988. Interim progress report: Snow management and meltwater enhancement. Project 3.2-3, Canada/Saskatchewan Economic & Regional Development Assistance (ERDA) Fund: December 21, 1988. [CS-88091] - 17 pp.

Nicholaichuk, W., R. Grover and J. Whiting, 1988. Herbicide, nutrient and water balance from an irrigated field. Water for World Development, Vol.III - Agriculture, Irrigation, and Drainage; Environment, Proceedings, 6th IWRA World Congress on Water Resources, 29 May - 3 June 1988, Ottawa, Ontario, International Water Resources Association, 255-262

Nicholaichuk, W., R. Grover and J. Whiting, 1988. Herbicide, nutrient, and water drainage from an irrigated field. [CS-88057] - 11 pp.

Nicholaichuk, W., R. Grover and J. Whiting, 1988. Interim progress report: Herbicide, nutrient and water drainage from an irrigated field. [CS-88087] - 6 pp.

Nicholaichuk, W., B. McConkey and H. Steppuhn, 1988. The role of a small agricultural watershed in addressing soil and water concerns. Proceedings, Canadian Hydrology Symposium No.17 - 1988, Canadian Research Basins: Successes, Failures and Future, CHS-88-SCH, 9-11 May 1988, Banff, Alberta, Associate Committee on Hydrology, National Research Council of Canada (NRCC No.30416), 155-157

Nicholaichuk, W. and H. Steppuhn (Editors), 1988. Proceedings of the Symposium on Water Management Affecting the Wet-to-Dry Transition: Planning at the Margins, Water Studies Institute, 8-9 November 1988, University of Regina, Regina, Saskatchewan, Water Studies Institute, 291 pp.

Ommanney, C.S.L., 1988. 1980-1985 quadrennial report to the World Glacier Monitoring Service on Canadian glacier variations, mass balance and special events, 230 pp. Published in Fluctuations of Glaciers 1980-1985 (Vol.V), W. Haeberli and P. Müller, World Glacier Monitoring Service (Compilers), A contribution to the Global Environmental Monitoring System (GEMS) and the International Hydrological Programme, International Association of Hydrological Sciences (International Commission on Snow and Ice) and United Nations Environment Programme and Unesco

Ommanney, C.S.L., 1988. Glacier names of the Rocky Mountains. [CS-88010] - 20 pp.

Ommanney, C.S.L., 1988. Snow and ice research in Canada. [CS-88025] - 22 pp.

Ommanney, C.S.L. and Young, G.J., 1988. Research on Canadian glaciers within the IHD/IHP. Proceedings, Canadian Hydrology Symposium No.17 - 1988, Canadian Research Basins: Successes, Failures and Future, CHS-88-SCH, 9-11 May 1988, Banff, Alberta, Associate Committee on Hydrology, National Research Council of Canada (NRCC No.30416), 21-28

Perla, R.I., 1988. Avalanche. The Canadian Encyclopaedia, Second Edition, Volume I: A - Edu, J.H. Marsh (Editor), Hurtig Publishers, Edmonton, Alberta, 153

Perla, R. and J. Banner, 1988. Calibration of capacitive cells for measuring water in snow. Cold Regions Science and Technology, 15(3), October, 225-231

Perla, R. and R.A. Sommerfeld, 1988. On the morphology and size of snow grains. A Merging of Theory and Practice: Proceedings of the International Snow Science Workshop, 12-15 October 1988, Whistler, B.C., Canadian Avalanche Association, 34-36

Polson, J. and J. Whiting, 1988. Use of remotely sensed data for hydrologic investigations in Wood Buffalo National Park. Contract No.KW504-7-1152, SRC Publication No.E-905-14-E-88, Saskatchewan Research Council, Saskatoon. [CR-88004] - 11 pp.

Pourchet, M., J.F. Pinglot, L. Reynaud and G. Holdsworth, 1988. Identification of Chernobyl fall-out as a new reference level in Northern Hemisphere glaciers. Journal of Glaciology, 34(117), 183-187

Prowse, T.D., 1988. Field determination of ice jam porosity. Proceedings, 9th International Symposium on Ice, IAHR, K. Saeki and K. Hirayama (Editors), 23-27 August 1988, Sapporo, Japan, Committee on Ice Problems, International Association for Hydraulic Research, Vol.2, 316-325: Discussion and reply, Vol.3, 275-277; Errata, Vol.3, 318

Prowse, T.D., 1988. Ice jam characteristics, Liard-Mackenzie rivers confluence: reply. Canadian Journal of Civil Engineering, 15(2), 277-278

Prowse, T.D., M.N. Demuth and C.R. Onclin, 1988. Strength and energy balance of decaying river ice. Applied Hydrology in the Development of Northern Basins, Proceedings, 7th Northern Research Basins Symposium, 25 May - 1 June 1988, Ilulissat, Greenland, Danish Society for Arctic Technology, Copenhagen, Denmark, 29 March, 293-301

Prowse, T.D., M.N. Demuth and C.R. Onclin, 1988. Using the borehole jack to determine changes in river ice strength. Proceedings, 5th Workshop on Hydraulics of River Ice/Ice Jams, 21-24 June 1988, Winnipeg, Manitoba, 283-302

Pupp, C. and G. Grove, 1988. Ground water in Atlantic Canada: overview of a series of reports by Environment Canada with the assistance of provincial governments. Proceedings, International Groundwater Symposium on Hydrogeology of Cold and Temperate Climates and Hydrogeology of Mineralized Zones, C.L. Lin (Editor), 1-5 May 1988, Halifax, Nova Scotia, International Association of Hydrogeologists, Atlantic Canada Region, 229-234

Pupp, C. and G. Grove, 1988. Ground water in Canada: use, quality and management. Water for World Development, Vol.II - Hydrology and Groundwater, Climate, Energy, Proceedings, 6th IWRA World Congress on Water Resources, 29 May - 3 June 1988, Ottawa, Ontario, International Water Resources Association, 409-419

Roberts, M.C., 1988. The depth and areal extent of overburden at selected sites within the University of British Columbia Forest, Maple Ridge, B.C.: a feasibility study. Contract No.KW504-9-0304, Department of Geography, Simon Fraser University, Burnaby, British Columbia. [CR-88005] - 12 pp. + map

Schmok, J., 1988. 1988 mass-balance determination of Sentinel, Place and Helm Glaciers, British Columbia. Contract No.KW504-8-0865/01-SB, Department of Geophysics and Astronomy, University of British Columbia, Vancouver, British Columbia. [CR-88002] - 22 pp.

Steppuhn, H. and W. Nicholaichuk, 1988. The role of snow and rain in Prairie wetlands. Proceedings of the Symposium on Water Management Affecting the Wet-to-Dry Transition: Planning at the Margins, W. Nicholaichuk and H. Steppuhn (Editors), Water Studies Institute, 8-9 November 1988, Regina, Saskatchewan, 163-174

Vandenberg, A., 1988. A digital simulation of moisture movement through a layered column of sand and AFBC solid waste: preliminary report, February 1987. [CS-88015] - 43 pp.

Vandenberg, A., 1988. A physical model of vertical infiltration, drain discharge and surface runoff for layered soils: preliminary report. NHRI Paper No.42, National Hydrology Research Institute, IWD Technical Bulletin No.161, Inland Waters Directorate, Saskatoon, Saskatchewan, 76 pp.

Wankiewicz, A., 1988. GEWEX - Global Energy and Water Cycle Experiment. Evaporation and Evapotranspiration Processes, F.J. Eley (Editor), Proceedings of Workshop, 20-21 May 1987, Saskatoon, Saskatchewan, Canadian Climate Centre Report No.88-2, Atmospheric Environment Service, National Hydrology Research Centre, Saskatoon, Saskatchewan, 94-95

Wankiewicz, A., 1988. Snowmelt observation by microwave satellite. AGU Fall Meeting, 6-11 December 1988,San Francisco, California, E⊕S, Transactions, American Geophysical Union, 69(44), 1 November, abstract, 1214

Warwick, W.F., 1988. Morphological deformities in Chironomidae (Diptera) larvae as biological indicators of toxic stress. Toxic Contaminants and Ecosystem Health: a Great Lakes Focus, M.S. Evans (Editor), Advances in Environmental Science and Technology No.21, Wiley-Interscience Publication, John Wiley and Sons, Toronto, 281-320

Warwick, W.F., J. Fitchko, P.M. McKee, D.R. Hart and A.J. Burt, 1987. The incidence of deformities in *Chironomus* spp. from Port Hope Harbour, Lake Ontario. Journal of Great Lakes Research, 13(1), 88-92

Warwick, W.F. and N.A. Tisdale, 1988. Morphological deformities in *Chironomus, Cryptochironomus,* and *Procladius* larvae (Diptera: Chironomidae) from two differentially stressed sites in Tobin Lake, Saskatchewan. Canadian Journal of Fisheries and Aquatic Sciences, 45(7), 1123-1144

Zentner, R.P., C.A. Campbell, F. Selles, B. McConkey, W. Nicholaichuk and J.D. Beaton, 1988. Nitrogen fertilizer management for maximum economic yields of spring wheat in Southwestern Saskatchewan. Proceedings, Soils and Crops Workshop, 18-19 February 1988, University of Saskatchewan, Saskatoon, Saskatchewan, Vol.2, 309-321

Zentner, R.P., C.A. Campbell, F. Selles, B. McConkey, W. Nicholaichuk and J.D. Beaton, 1988. Snow trapping and nitrogen fertilizer management for spring wheat production in southwestern Saskatchewan. [CS-87048] - 17 pp.

Zentner, R.P., C.A. Campbell, F. Selles, B. McConkey, W. Nicholaichuk and J.D. Beaton, 1988. Snow trapping and nitrogen management for zero tilled spring wheat in southwestern Saskatchewan. Proceedings, Great Plains Soil Fertility Workshop, Maximum Wheat Yield Production Symposium, March 1988, Denver, Colorado, Vol.2, 147-158

Publications and Reports of the Hydrometeorological Research Division

[HRD = Contributions of the Hydrometeorological Research Division]

Bauer, D.J. and L.E. Welsh, 1988. Frequency analysis of meteorological drought in the Saskatchewan portion of the South Saskatchewan River basin. [HRD-88-02] - 110 pp.

Eley, F.J., 1987. Current research needs in mountain hydro-meteorology. [HRD-87-01] - 68 pp.

Eley, F.J. (Editor), 1988. Proceedings of the Workshop on Evaporation and Evapotranspiration Processes, May 20 and 21, 1987, National Hydrology Research Centre, Saskatoon, Saskatchewan. [HRD-88-03] - 108 pp.

Eley, F.J. and R.G. Lawford, 1988. Potential climatic impacts of water transfers. Proceedings of the Symposium on Interbasin Transfer of Water: Impacts and Research Needs for Canada, W. Nicholaichuk and F. Quinn (Editors), NHRI Symposium No.1, National Hydrology Research Centre, Environment Canada and Canadian Water Resources Association, Saskatoon, Saskatchewan, 319-333

Kite, G.[W.], 1988. Analyzing NOAA satellite images from magnetic tape. [HRD-88-05] - 70 pp.

Kite, G.W., 1988. Calculating streamflow from natural salinity differences. Water for World Development, Proceedings, VIth IWRA World Congress on Water Resources, 29 May - 3 June 1988, 222-231. Also - Abstracts, Paper No.410A8, 6th IWRA World Congress on Water Resources, 29 May - 3 June 1988, Ottawa, Ontario, Vol.2, 4 pp.

Lawford, R.G., 1988. Climatic variability and the hydrological cycle in the Canadian North: knowns and unknowns. Proceedings, Third Meeting on Northern Climate, Canadian Climate Program, 7-8 September 1988, Whitehorse, Yukon Territory, Atmospheric Environment Service, Downsview, Ontario, 143-162

Lawford, R.G., 1988. Impacts of the 1988 drought in the Canadian Prairies. The Drought of 1988 and Beyond, Proceedings of a Strategic Planning Seminar co-sponsored with the National Academy of Science and Resources for the Future, October 18, 1988, Washington, D.C., National Climate Program Office/NOAA, Rockville, Maryland, extended abstract, 165-176 [HRD-88-16]

Lawford, R.G., 1988. An overview of the hydrometeorology of the Canadian portion of the western Cordillera. Abstracts for the AGU Fall Meeting, E⊕S, Transactions, American Geophysical Union, 69(44), 1 November, 1214

Lawford, R.G., 1988. Towards a framework for research initiatives involving the impacts of climatic variability and change on water resources in the Canadian Prairies. Symposium/Workshop Proceedings, The Impact of Climate Variability and Change on the Canadian Prairies, B.L. Magill and F. Geddes (Editors), 9-11 September 1987, Edmonton, Alberta, Alberta Climate Advisory Committee, Alberta Environment, Edmonton, Alberta, 275-306

Ripley, E.A., 1988. Drought prediction on the Canadian Prairies. [HRD-88-19] - 137 pp.

Strong, G., 1988. The prediction of meteorological hazards using artificial intelligence. Proceedings, International International Symposium on Cold Region Development (ISCORD '88), Y. Chen, Z. Yuan and J. Gao (Editors), 9-13 August 1988, Harbin, China, Vol.4, 324-333

Whiting, J. and E. Wheaton, 1987. The design of a western Canadian real-time system for integrated forecasting of basin specific floods and low flows. Contract No.01-SG KW504-6-1128, SRC Technical Report No.195, Publication E-905-6-B-87, Saskatchewan Research Council, Saskatoon, Saskatchewan. [HRD-87-02] - 108 pp.


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Director's Comments

Since the National Hydrology Research Centre opened in October 1986, staff have endeavoured to create research programs that not only address the environmental issues of the present, but anticipate those of the future. In keeping with this objective, a number of significant organizational changes have been made in the last two years.

Shifting to a more interdisciplinary mode of working, the Institute has developed two major research thrusts: Hydrological Sciences and Environmental Sciences. Both programs comprise projects designed to meet perceived future issues related to the management of water resources and the aquatic environment. Details of these are given in the body of this report.

A third program initiative has been undertaken to deliver integrated scientific information on current issues and to provide advice on policy. Knowledge and understanding of the natural environment are the products of research activity, and there is a need to disseminate scientifically correct information to professional water managers and to the general public.

In 1990, the Institute developed a new strategic plan to meet the challenges of the coming decade. Conceptually, the plan addresses both program content and scientific excellence. Perhaps one of its more useful aspects is the inclusion of criteria for assessing research projects. Although not yet made final, the criteria will emphasize both scientific excellence and the broad priorities of the Department of the Environment.

During the reporting period, the Institute benefited from having Rick Lawford as Associate Director for a one year assignment. Of particular value was his assistance in the development of the long term strategic plan to guide research and management directions over the next few years. Mr. Lawford's term with NHRI has also improved the contacts needed to maintain close working relationships with the Hydrometeorological Processes Division of the Atmospheric Environment Service.

It should be noted that NHRC is the only DOE national research centre in the West. For logistical reasons, most of the field work is undertaken in the five western provinces and the two northern territories. This geographical area, particularly the North, must reconcile development with environment, and the Institute's programs can assist in resolving issues as they arise. Northern and western Canada may also be significantly affected by possible climate change owing to atmospheric hot-house gas build up. Economic consequences could be enormous. Research must provide sufficient understanding to ensure that actions and policies are sound. Because of the environmental vulnerability of the western and northern region and the lower scientific personnel density in the West, the Institute has a high potential to influence and encourage R & D that supports national environmental issues.

Over the reporting period, the Institute has profited from its support of postdoctoral fellows, graduate students and visiting scientists. Many staff have received university honorary appointments as adjunct professors, with the vast majority held at the University of Saskatchewan. These and other contacts, combined with seminars and conferences organized by staff and management, have developed a comprehensive scientific network in Canada, the U.S.A., and overseas.

Scientific staff can only provide timely advice and information if they keep fully cognizant of the latest developments in their areas of expertise. To do this, they need the support of up-to-date facilities and equipment. Funding is and always will be an issue. Fortunately, the Centre has an enthusiastic, conscientious and imaginative financial and materiel management staff. Resources are used effectively to meet program needs.

Last but not least, the Government's Green Plan introduces a new framework for the research activity in NHRC. This new plan will substantially influence the direction of research programs as they develop over the next year or so.

STAFF

Dr. T.M. Dick
P. Richard, Secretary
S.D. Baird

Associate Director

The Associate Director position was established for a one year term to deal with issues identified by the NHRI Management Review of 1989. Rick Lawford, Chief of the Hydrometeorological Processes Division, held the appointment from January to December 1990, assisted by Cindy Heseltine and Sharon Mojelski. His major tasks were to implement changes in planning and administrative procedures, and to provide support to the Director to enable him to dedicate more time to external relations.

Administrative issues were addressed in a collegial way. A task force chaired by the Associate Director and composed of members from all sections of the Institute successfully resolved a number of issues, including interactions with the media, reporting long distance telephone calls, and conference reporting. The task force also provided comments and suggestions on such matters as publishing procedures and the role and organization of the central registry.

As Associate Director, Rick Lawford became involved in a wide variety of management activities. He provided recommendations on hiring strategies, budgets and organizational structures; coordinated an extensive training program for NHRI project leaders and chiefs that included courses on appraisals, interpersonal relations, career planning, financial management and media interview skills; conducted career interviews with all full-time staff to provide an information base for the Institute's human resources plan; developed proposals relating to Environment Canada's Green Plan; and launched several initiatives to strengthen the linkages between the Canadian Climate Centre and NHRI by stimulating dialogue between the two groups, particularly in the area of climate and hydrology.

During his one-year appointment, Rick co-chaired a Canada/U.S. Symposium on Climate Variability and Change on the Great Plains, participated in an IGBP conference in Chile dealing with the hemispheric responses to global change, presented papers at four other national conferences related to climate and hydrology, and put considerable effort into a number of GEWEX (Global Energy and Water Experiment) activities, both at the international and the national levels. As well as participating in scientific meetings, he organized two workshops on science policy and prepared the proceedings for publication. The first of these documents, "Enhancing the Image of NHRC's Science and Scientists," includes recommendations that have been presented to the management team: the second, "NHRI's Blueprint for the Nineties," sets out a strategic plan for the Institute's future.

STAFF

R.L. Lawford
C. Heseltine, Secretary

Dr. Melinda Brugman takes mass balance measurements of Sentinel Glacier in British Columbia as part of an NHRI research program to model alpine hydrological processes and to determine the total ice loss since original maps of the glacier were prepared in the 1950s. Data from field studies of glaciers will be used in the new CRYSYS program to study environmental change.

Hydrological Sciences Division

The research strategy of the Hydrological Sciences Division emphasizes the investigation of climate and hydrology, land/atmosphere processes, and the northern environment. Interdisciplinary research is conducted on hydrological processes that characterize elements of the hydrologic cycle other than groundwater. Models and theories are being developed to identify future trends in the availability and use of water, while the knowledge base to support departmental policies relating to the sustainable development of water resources continues to grow. Linkages have been developed with the Atmospheric Environment Service in the areas of climate change and hydrometeorology, and national and international partnerships have been formed with research institutes, universities, and government agencies. In the past year, the Division organized, hosted, and participated in seminars and conferences at regional, national and international levels.

CLIMATE AND HYDROLOGY

A changing climate could have significant impacts on water supply in western Canada. In mountain regions, source of most of the water supplied to the semi-arid prairies, climate change will influence water storage in glaciers, timing of water release, precipitation patterns, evaporation regimes, and the balance between water in groundwater and surface water systems. In order to gain a better understanding of the relationship between climate and hydrology in the mountain environment, three main research aims have been developed: to obtain data on past climates from the information preserved in ice cores, to predict water supplies from glacier reservoirs in the mountains, and to develop techniques for assessing soil moisture from satellite images.

Proxy Climate Data from Ice Cores

G. Holdsworth
M.N. Demuth

Analysis of ice cores taken from a field site on Mount Logan in the Yukon has disclosed significantly lower snow accumulation rates from A.D. 1700-1860 than from 1860 to 1987. It has also revealed the existence of "teleconnections" (ultra long-distance correlations) between the Mount Logan net snow-accumulation time-series and some instrumental precipitation time-series elsewhere in the Northern Hemisphere. Another important finding is that the main atmospheric pollution of high-altitude snow is by volcanic-eruption gas plumes and possibly forest fires. Apart from recent contamination by radio-nuclides from atmospheric nuclear-weapons testing, there is no evidence of other anthropogenic acid pollution, such as is found in Greenland.

An automatic weather station was established at the Eclipse site in the Saint Elias Mountains to record snow-surface meteorological variables throughout an annual period and to help interpret some aspects of the ice core data. Temperature and wind data were collected for the winter 1989/90. Depth-sensor problems were corrected during the summer of 1990 and the station operated satisfactorily throughout the 1990/91 winter, providing snow depth as well as wind and temperature data sufficient for the core analysis.

The electrical, hydraulic and mechanical assembly work for the new Canadian-Rufli-Rand Ice Core Drill was completed and all drill components were bench tested; the drill was then field-tested in the Saint Elias Mountains at the Eclipse station. An engineering and operational/logistics manual for the new drill system is now being prepared.

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Satellite Monitoring of Snow and Soil Moisture

A.C. Wankiewicz

Nimbus-5 ESMR observations of 17 different watersheds were used to estimate spring runoff in the Rocky Mountains and Plains regions. Average snowmelt runoff and microwave brightness are correlated. For Rocky Mountains watersheds, 5,000 to 20,000 km in area, the results are almost as good as the conventional snow courses for 1973-1976. Inter-annual variations in snowpack and brightness are localized and their significance is being tested as a function of watershed area and alpine fractional area. For the Plains, a good multiple correlation was established between microwave brightness, spring runoff, and previous October streamflow. In the Iron Creek (3,500 km) and Antler River (3,200 km) basins, air temperature was measured at four and six climate stations respectively, and a microwave emissivity index computed as the ratio of monthly mean brightness to surface temperature. This index could be used to monitor monthly basin moisture status. Other developments include further digital data analysis, streamflow separation, and airphoto interpretation of the Plains basins. Twenty-three ocean areas were analysed as potential calibration targets with an ocean-atmosphere model.

Microwave remote sensing of snow

R.I. Perla

The real permittivity of 200 snow samples, measured with a wide range of density and wetness in a capacitive cell at 1 MHz and at 0°C, fits three empirical functions. In agreement with microwave measurements, the empirical constant was found to be 0.4 for wet snow, but higher at both the dry (0.7) and very wet extremes (0.6). These values are consistent with snow microstructure modelled as a sintered ice skeleton with water inclusions disconnected for low volume proportion of water (vW) and connected as vW→1. Other developments in this study include the installation and testing of an Eikonix image-analysis system.

Mountain Hydrology and Glacial Meltwater

M.M. Brugman

With the addition of an alpine hydrologist to the staff of NHRI we have been able to proceed with the development of a comprehensive mountain hydrological and glaciological program. Research programs at Peyto, Sentinel, Helm and Place glaciers have been re-established and measurements of the winter, summer and net balances obtained to determine the total ice loss since original maps were prepared at the start of the International Hydrological Decade in 1965. Collaboration continues with university scientists. An energy-balance study of Peyto has been undertaken with D. Scott Munro of the University of Toronto, while Gordon J. Young of Wilfrid Laurier University has re-mapped the glacier to establish geodetic limits against which mass balance records can be assessed.

A view of Garibaldi Lake at sunset taken from the base of Sentinel Glacier where a small hut houses equipment, food, and sleeping quarters for NHRI researchers and visiting scientists working on the glacier.

The State of Canada's Glaciers

C.S.L. Ommanney

Recent glacier activity and studies have been documented as part of a global project sponsored by the U.S. Geological Survey for a satellite image atlas of glaciers of the world. The Canadian report on glaciers in the Rocky Mountains consolidates glaciological information collected over the last century and provides a solid foundation for planning future work.

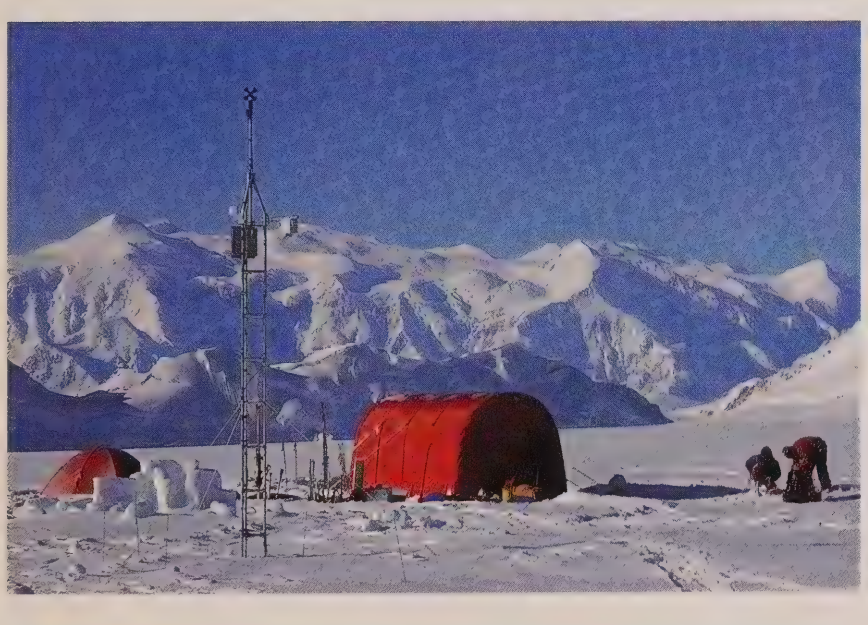
CRYSYS - Glacier Component

C.S.L. Ommanney
M.M. Brugman
M.N. Demuth

Canada has embarked on a new program to use remote sensing and field studies of glaciers as tools to study environmental change. The program, called CRYSYS (CRYospheric SYStem to monitor global change in Canada), is part of a collaborative venture with the National Aeronautics and Space Administration and the Canada Centre for Remote Sensing. Success in this study will enable us to relate ground-based studies of snow water-equivalent, snow and ice properties, snow and ice extent, mountain meteorology, etc. to larger-scale hydrological and glaciological scenarios and permit the future use of remote sensing for observing and forecasting regional hydrology. The study will make use of Earth Observing System satellites that will be launched later this decade. NHRI has made a firm commitment to CCRS and NASA to carry out ground-truthing and inventory studies prior to launch. It is expected that the first field experiment will be carried out in the spring of 1991 in conjunction with a NASA overflight.

Technology Transfer

A new era in U.S./Canadian collaboration on glacier research was ushered in with the creation of a North American Committee on Climate and Glaciers and the subsequent successful organization of a workshop on glacier mass-balance methodology in Seattle, sponsored by the National Research Council of Canada Subcommittee on Glaciers. NHRI scientists are now collaborating with Gunnar Østrem of Norway on a new edition of the glacier mass balance manual that has served as an international standard for the last 25 years.



The Eclipse weather station in the Saint Elias Mountains was the site for testing the new Canadian-Rufli-Rand Ice Core Drill. Data from ice samples taken at this site are used in interpreting ice core records retrieved from nearby Mount Logan, seen in the background of the picture. Ice cores preserve information on past climates and atmospheric pollution and can help scientists understand the links between climate and hydrology, past, present, and future.

NORTHERN ENVIRONMENT

The fragility and low regenerative capacity of northern water ecosystems render them particularly vulnerable to detrimental effects from development. The goals of the Northern Environment Project are to assess the effects of major energy and other economic developments on northern hydrological systems, to evaluate the ecological impact of pollutants introduced by airborne transport or by local development, and to develop the information base necessary to determine the factors that control water availability in the North.

Breakup and related environmental effects

T.D. Prowse
M.N. Demuth
H.A.M. Chew

Spring ice breakup is often the most spectacular and energy-intensive event of the annual hydrologic cycle on northern rivers. Flood-related effects of breakup are evident in almost all regions of Canada, with conservative estimates of annual damage totals being approximately $20 million. Other consequences of breakup are gaining greater recognition. Considered from an ecological perspective, for example, the enhanced erosion and scouring action resulting from ice runs may determine the annual biological set-point for some riverine systems.

Studies of breakup processes have focused on predicting the severity of ice runs and ice jamming from changes in ice cover strength. Meteorological and ice strength measuring equipment has been used to quantify the decrease in ice strength under radiation decay. Results from studies on the Liard River in the Northwest Territories and a small experimental lake near Saskatoon, Saskatchewan indicate that the development of as little as a 10% melt fraction will result in a four-fold decrease in the strength of columnar ice as compared to its strength at 0°C. Laboratory studies have been initiated to define the structure-geometry that explains such a dramatic reduction and to quantify the changes in the optical properties of ice that accompany structural radiation decay: changes that have significant implications for biological productivity beneath ice, particularly in lakes.

Freeze-up and related environmental effects

G. Tsang

Freeze-up processes on northern rivers are largely controlled by the growth and evolution of dynamic ice types, specifically frazil and anchor ice. Problems related to frazil ice growth are diverse, ranging from restrictions on hydro-power operation to effects on riverine biota and fisheries. To improve our understanding of frazil and anchor ice dynamics, a circular laboratory flume has been constructed and made the focus of a number of studies. Part of the financial support to conduct this work has been provided by Hydro Quebec, Manitoba Hydro, Ontario Hydro and the New York Power Authority. To date, video and digital data about anchor ice formation and frazil concentration/distribution have been collected under a range of hydro-thermal conditions. Analysis of these results is under way.

Using a borehole jack, Michael Demuth and Darren Schill test the internal strength of the ice cover on the Liard River prior to Spring breakup. Energy balance experiments detail the thinning and structural decay of the ice under the influence of solar radiation

Snowmelt runoff in permafrost basins

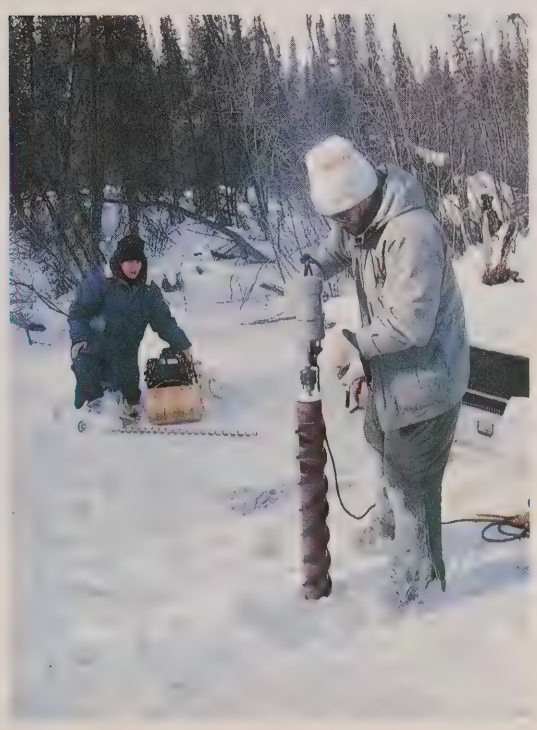
P. Marsh

Field and laboratory work is aimed at improving the ability to model snowmelt runoff in permafrost environments, a capability essential for predicting water supply and environmental change due to climate warming. Data collected at Resolute Bay, Northwest Territories include snow surface energy balance, snow and soil temperature, snow survey, total soil moisture (frozen plus liquid) using gamma probes, and liquid water in the frozen soil using TDR (time-domain reflectometry). These data provide useful information on the movement of meltwater through the snowpack into the frozen soil and will improve our understanding of the annual cycle of changes in soil moisture.

MacKenzie Delta Hydrology

P. Marsh

Studies on the hydrology of lakes in the Mackenzie Delta focus on the potential environmental impacts of climate change, sea level rise, and/or hydroelectric development. Five years of lake water balance data for a number of lakes have been analysed, and the interactions between hydrologic sources of water and biogeochemical processes within the delta ecosystem evaluated, particularly with respect to flood hydrology, evaporation and nutrient supply.



In the Northwest Territories, near the Liard River, technician Cuyler Onclin drills for core samples of ice on Manners Creek. The ice cores will undergo chemical isotope analysis as part of a study investigating the water balance of wetlands in permafrost regions.

Wetlands in permafrost environments

H.D. Craig
T.D. Prowse

The abundant wetlands of Canada's north represent a valuable ecological resource, the hydrology of which is at present poorly understood. A field study has been initiated on Manners Creek near Fort Simpson, Northwest Territories to improve our understanding of wetland-permafrost processes and to assess potential hydrologic impacts of climate change. Using geochemical and isotopic methods, flow paths within the wetlands have been investigated and an assessment made of their significance to runoff generation. Among other things, the study has shown that some of the wetland ponding and restriction to lateral flow is dependent on the presence of permafrost-hydrologic divides. Current plans are to assess their overall significance and to model the change in the hydrologic regime that would result from a meltout induced by climate change.

Northern Hydrology

In July 1990, NHRI hosted Canada's first Symposium on Northern Hydrology. Co-sponsored by Environment Canada's Western Committee of Regional Executives, the Canadian Water Resources Association and the Water Resources Division of the Department of Indian and Northern Affairs Canada, the Symposium drew approximately 130 participants, with representatives from the major Nordic countries including Denmark (Greenland), Finland, Norway, Sweden, United States (Alaska) and the USSR.

The Symposium was the venue for the official release of NHRI's Science Report No.1 entitled "Northern Hydrology: Canadian Perspectives." The book begins with an overview of northern hydrology and in separate chapters deals with past, present and future research in

specialized fields of northern hydrology, including glacier hydrology, groundwater hydrology, hydrology of floating ice, permafrost hydrology, snow hydrology, regional energy balances, regional hydrology, water quality and water regulation.

LAND/ATMOSPHERE PROCESSES

Knowledge of land/atmosphere interactions is becoming increasingly important in evaluating the effects of climate variation and change on water resources. The Land/Atmosphere Processes Project has contributed to this knowledge by conducting basic research into evapotranspiration and into snow transport and accumulation. A new technique of measuring suspended sediment in rivers has been developed and field studies of snowfall interception, blowing snow and vapour transfer have been carried out in northern and western regions of Canada.

Suspended Sediment Transport

B.C. Kenney

Suspended sediments have been linked to the transport of toxic contaminants in many rivers. Quantification of the potential hazard has been limited by the difficulty and high cost of sampling using continuous-flow centrifuge technology. To overcome some of these difficulties, a totally passive sampler has been developed at NHRI to collect time-integrated samples of horizontal flux of suspended material in rivers. The samplers are lined with glass and are cleaned to rigid specifications in the laboratory prior to installation in the river. They are inexpensive and can be deployed in sufficiently large numbers to permit identification of sources of toxic contaminants. Field tests are currently under way at sites across Canada in cooperation with the Water Quality Branch of Environment Canada and the Centre Saint-Laurent.

Evapotranspiration

R. Granger

NHRI is assessing existing techniques and developing new approaches for modelling evapotranspiration. Evaluation of the Complementary Relationship Areal Evapotranspiration (CRAE) model developed in Canada has identified several areas for improvement, particularly with regard to the model's energy algorithms and vapour transfer function. Development of an improved radiation model is under way, and a vapour transfer relationship appropriate for daily time scales has been identified.

Field studies have facilitated verification and refinement of a new approach to the estimation of evapotranspiration, one which makes use of feedback relationships between the surface and overpassing air layer and has the advantage of requiring no prior calculation of potential evapotranspiration. Other studies have explored the application of remote sensing to the operational estimation of areal evapotranspiration and revealed a potential use for remotely-sensed surface temperature data in the evaporation models currently under development.

At Kernan Crop Development Farm, University of Saskatchewan, a mobile instrument mast takes automatic measurements of temperature, humidity, turbulence and radiation at different points in a field of actively growing canola. These profiles will be used in the assessment of areal evapotranspiraton as part of a project to develop new approaches to modelling evapotranspiration.

Snow Transport

J. Pomeroy

Field measurements in the snow transport study are used to develop physically-based computer models of snow redistribution processes and their effect on regional and local water budgets. Such models are critical in assessing the effects of agriculture, forestry practices and global change on snow water supply and quality; for example, NHRI's Prairie Blowing Snow Model indicates that in the relatively sheltered northern Prairies roughly one third of annual snowfall is lost to blowing snow transport and sublimation. This loss more than doubles as one moves to the treeless southern Prairies. In 1990/91, three field campaigns were conducted to gather data to extend NHRI's analysis of snow losses and redistributions.

In the Kananaskis Valley, a study of snowfall interception is helping identify the accumulation and sublimation processes that lead to differences in snowpacks between forests and open areas. On the Prairies, the focus of research is the horizontal development of blowing snow transport downwind of a shelter belt. Results of the study are enhancing our understanding of snow management benefits gained from windbreaks in this drought-prone region. In the Northwest Territories, near Resolute Bay, a comprehensive study has quantified the effects of blowing snow on snowcover redistribution and chemistry in Arctic regions. Results indicate that sublimation of blowing snow concentrates contaminants held in snow crystals up to three-fold and it seems likely, therefore, that when snow is deposited near water-courses, the elevated contaminant levels may exacerbate the "acid flush" through aquatic ecosystems in Spring.

Blowing snow impedes technicians' progress in operating equipment to collect data for a snow transport study. A model developed at NHRI indicates that roughly one third of annual snowfall is lost to blowing snow and sublimation in the relatively sheltered northern Prairies. In the treeless southern Prairies, this loss more than doubles.

TECHNICAL SUPPORT

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T.E. Carter
J.A. Dalton
N. Hedstrom
M. Griffin
C.R. Onclin
R. Reid
D. Schill

Technical staff in the Hydrological Sciences Division operate a central geotechnical laboratory service for the Institute and provide direct support to glaciological, hydrologic, geologic, and remote sensing studies. Much of the fieldwork is done at locations in the North, on glaciers and northern rivers. In the past year, this included collection of glaciological data for use in a study to model alpine hydrological processes; measurement of changes in ice strength during Spring breakup on the Liard River, Northwest Territories; and the design and construction of a backpackable hydrothermal drill for use in ablation studies on Peyto, Sentinel and Place Glaciers. Work was also completed on the design and construction of a special purpose meteorological station for Arctic research.

Other technical support activities include analysis of remotely-sensed data to support satellite snow and soil moisture research; soil sample extraction and laboratory analysis; design and testing of an automated system for soil water extraction; and testing of experimental procedures to determine sublimation rates of snow from the branches of coniferous trees.

An abandoned farm well near Nokomis, Saskatchewan. The water flows from an aquifer deep in the earth, and as it comes into contact with the air, iron precipitates out leaving distinctive orange deposits on logs and rocks.

Environmental Sciences Division

The Environmental Sciences Division was formed in 1990 through the amalgamation of the Aquatic Ecology and Groundwater Divisions and now consists of two projects: Nutrients Impacts and Rehabilitation, and Groundwater and Contaminants. In keeping with NHRI's mission, research has generally been confined to western Canada, and staff have striven to interact with universities, industry, and provincial government agencies. During the past year, research activities have diversified with the addition of new scientific and technical staff; however, in order to provide the knowledge base for the implementation of departmental strategies and the Green Plan, the focus of the Division's work has remained on nutrient and contaminant fate and impacts.

NUTRIENT IMPACTS AND ECOSYSTEM REHABILITATION

Pollution of rivers and lakes from municipal, industrial and agricultural sources can degrade the natural aquatic environment and threaten the health of fisheries and wildlife. Environment Canada's Green Plan indicates Canadians are concerned about the links between the degradation of water resources and their health. At NHRI, aquatic ecologists focus their research on the impacts of nutrients and contaminants on the biology of aquatic organisms and the transfer of these chemical compounds through all levels of the food web. Using the knowledge gained from their studies, scientists also develop management techniques for the restoration of degraded aquatic habitats, an important aspect of sustainable development.

Prairie Lake Ecology

M.S. Evans
R.D. Robarts
W. F. Warwick

The many small freshwater and saline lakes of the Prairies are important recreational areas and wildlife habitats. To manage these systems within the concepts of sustainable development and global warming requires an in-depth understanding of their structure and functioning. Freshwater and saline prairie lakes appear to respond to nutrient loads (nitrogen and phosphorus) in unique ways and the reasons for this remain to be elucidated. Eutrophication continues to be a major environmental problem in western Canada.

Studies of phytoplankton (algal), zooplankton, benthic invertebrates and heterotrophic bacterial production have been undertaken in productive and non-productive saline and freshwater lakes to determine energy transfer through the food webs of these different lake types. In particular, studies are under way to ascertain the dependence of bacterial production on phytoplankton production, to assess whether heterotrophic bacteria contribute to summer deoxygenation in productive lakes, to discover the primary limiting nutrients to phytoplankton growth in non-productive saline lakes, and to identify linkages between benthic and open-water communities. Results from these studies are helping NHRI scientists develop better management strategies for long-term sustainability of prairie water supplies by enabling them to pinpoint the particular factors that cause prairie lakes to respond differently to nutrient loads.

Nutrient/Contaminant Impacts to Large Rivers

M.L. Bothwell
J.M. Culp

The Thompson River in south-central British Columbia is a nutrient limited system in which the food web is primarily dependent on algal production. Research has focused on algal/nutrient/grazer interactions because phosphorus loading from municipal and pulp mill effluents was believed to be the cause of a dramatic increase of algal biomass in the Thompson in the 1970s. After phosphorus loading was cut by 60%, the algal biomass declined. However, recent experiments carried out by NHRI scientists suggest that the reduction in phosphorous loading is not solely responsible for reduced accumulations of river algae. At least one group of algal grazing invertebrates (Ephemeroptera) has increased by an order of magnitude during the

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late 1980s, suggesting that grazers are modifying the response of algal biomass to phosphorus in the Thompson River. Results of laboratory experiments confirm that under certain conditions mayflies can sharply reduce diatom mass. More lab and field experiments are now under way to discover if invertebrate grazers serve as top-down control agents of algal abundance in the river. Ultimately, these experiments may indicate whether grazer impacts have the potential to modify previously demonstrated nutrient/algal biomass relationships.

Also in the Thompson, a multi-year collaborative study with the National Water Research Institute has been undertaken to investigate the possible bioaccumulation of contaminants along a 100 km stretch of river downstream of the pulpmill effluents.

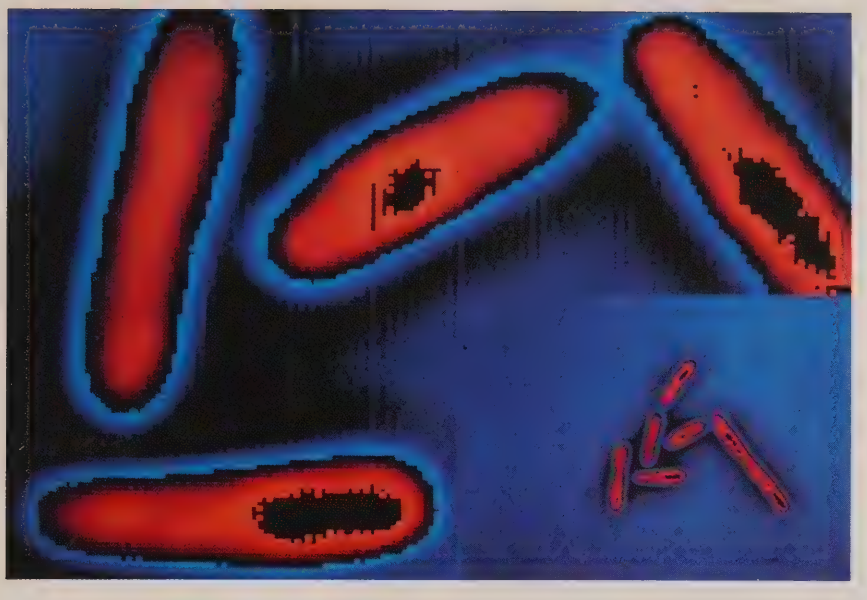
Dr. Max Bothwell scrapes algae from rocks in the Thompson River, British Columbia. Algal samples will be used in a study to quantify nutrient responses.

Aquatic Macrophytes in Prairie Lakes and Watercourses

P.A. Chambers

In the shallow lakes and rivers of the Canadian Prairies, submerged aquatic plants grow abundantly, attaining biomasses that are sufficiently large to block water movement, cause water quality problems in domestic and livestock drinking supplies, impair recreational activities and cause fish kills by depleting oxygen levels. The goal of this research program is to develop innovative management strategies for long-term control of aquatic weed growth in prairie lakes and watercourses. Research has been directed toward the discovery of safe environmental controls: for example, increasing flow rates during critical plant growth stages. Lime is being investigated as an additive that would bind with phosphate and render it unavailable to plants in lakes and dugouts. Results of this investigation show a dramatic decrease in aquatic weed abundance, with submerged plants virtually eliminated two to three weeks after treatment. New studies are now under way to examine the impact of lime additions on aquatic community structure and to determine the mechanism by which lime inhibits plant growth.

A summer student working in Dr. Patricia Chamber's research study brandishes a handful of weeds collected from a canal in southern Alberta. She wears a mask and snorkel to enable her to immerse her face in water and reach plants rooted in the bottom of the canal.



Images of a bacterial microcolony with the cell boundaries shown in pseudocolour. These images are used to monitor growth and activity of microorganisms in the presence of contaminants.

GROUNDWATER AND CONTAMINANTS

The Groundwater and Contaminants Project investigates the migration and remediation of contaminants such as pesticides, fertilizers, and acid mine drainage waters and brines in the subsurface. Much of the research is process-oriented, focusing on the hydrogeologic, biotic and chemical processes that control the fate and transport of solutes in both saturated and unsaturated groundwater regimes. The broad range of expertise of scientists in this project fosters an interdisciplinary approach to the study of groundwater and its contaminants, and facilitates improved decision-making on the impacts of toxic substances on the subsurface.

Mesoscale Model Aquifer Studies

J. R. Lawrence
M.J. Hendry R.A. Kirkland

The mesoscale model system is 4.6 m in height by 2.4 m in diameter and contains 65 tonnes of soil and aquifer materials. It allows researchers to avoid some of the environmental and other difficulties of field testing, and has been used successfully in two investigations of groundwater contamination during the past year. The first of these studies examined the effect of water infiltration into an alkaline fly ash disposal site and the impact of the resulting contaminant plume on the microbiota of the model aquifer system. A decline of three orders of magnitude in microbial activity occurred, while toxic effects were reflected also in lower numbers of organisms and reduced diversity. These results indicate that any failure of confinement technology at fly ash disposal sites could have serious impacts on the chemistry and microbiology of the underlying vadose and saturated zones.

In another study the mesoscale model system was used to investigate the transport and degradation of agricultural pesticides, a growing cause of public and regulatory concern. A rain simulation system ensured uniform coverage to the model aquifer, and sampling of soil sediment, pore waters and gas phase was carried out using a series of *in situ* collectors and sampling ports. Initial results of tests on the herbicide diclofop-methyl indicate transport of the herbicide through the upper 0.5 of the column with subsequent adsorption to sediment and degradation in the pore waters. These studies will continue through 1991/92.

Contaminant Transport Studies in Aquifers

G. van der Kamp
G. D. Grove

Groundwater from aquifers is a major source of water for many domestic, municipal, agricultural and industrial uses across Canada. Contaminant transport in aquifer systems is a vital area of research, and cooperative studies have been undertaken at two different sites in western Canada: the Condie aquifer in Saskatchewan and the Abbotsford aquifer in British Columbia. In Saskatchewan, work has concentrated on a long, narrow contaminant plume emanating from a sewage lagoon in the Regina area. Numerous multilevel piezometers have been installed to determine the three - dimensional geometry of the plume, and this detailed description will serve as a valuable test case for conceptual and numerical models of contaminant movement. This research has been carried out in cooperation with the Saskatchewan Research Council and the University of Waterloo. The study of the Abbotsford aquifer is being conducted jointly with the regional office of the Inland Waters Directorate in Vancouver and the Agassiz and Vancouver

Research Stations of Agriculture Canada. For the past several years, low but persistent levels of the nematicide 1,2-dichloropropane have been measured at selected locations within the aquifer. In 1990/91 a detailed study to determine the factors controlling the migration and fate of this chemical was begun; in the coming year, regular monthly monitoring for organic and inorganic parameters at several depths throughout the saturated and unsaturated zones will be initiated.

Acid Mine Drainage

Y.T.J. Kwong

Acid mine drainage is one of the most expensive environmental issues facing the mining industry today, and a particularly challenging problem in western Canada. NHRI's research is aimed at coupling geological and mineralogical information with water chemistry to determine the fate and transport of contaminants resulting from mining activities. A detailed study at the abandoned mine site on Mount Washington near Courtenay, British Columbia has identified the geochemical parameters controlling the acid generation and metal leaching processes that occur in the waste dumps and the open pit. Further studies have begun in the south MacMillan River area of the Yukon.

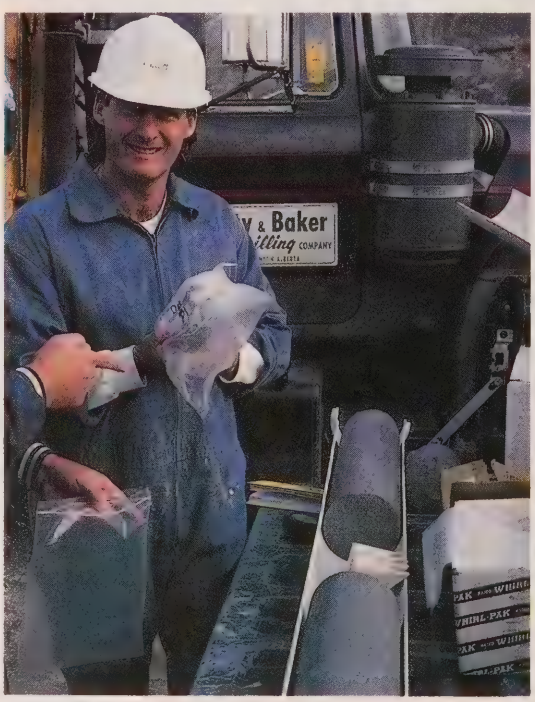
Contaminant Transport in Clayey Deposits

G. van der Kamp
M.J. Hendry

As contaminants are often contained within clayey deposits, an understanding of the processes controlling transport through such deposits is important to the protection of ground and surface waters. Two types of clayey deposits, tills and shales, are currently being studied at NHRI. One study is designed to age-date the porewaters of clayey tills at four sites in the Prairies. Preliminary results suggest the presence of old porewater (>20,000 years) in the low permeability tills.

Depositional crystals provide an historical record of the chemistry of earlier groundwater conditions. This large gypsum crystal is being used by NHRI groundwater scientists who are studying long-term transport of solutes and contaminants.

Another investigation explores the long-term transport through tills of oxygen-18, chloride and related inorganic ions. Groundwater flow rates through tills may be very slow, and transport of natural solutes and of contaminants may be largely by diffusion. This study of long-term transport, carried out in cooperation with the University of Waterloo, has obtained vertical profiles of oxygen-18 and chloride from several



Dr. Jim Hendry sub-samples shale core material from the Milk River field site. Samples will be analysed for isotopic ratios as part of a study to characterise the confining nature of Cretaceous shale.

sites that are indicative of advection-diffusion processes. For thick low permeability tills the profiles suggest very slow movement.

A third study is under way to determine whether and how brine from storage areas at potash mines in Saskatchewan is moving downward through underlying tills and clays. The work is being carried out in conjunction with the University of Saskatchewan and the Saskatchewan Research Council, the lead agency. It is funded by the Saskatchewan Potash Producers Association. Field and laboratory work has concentrated on the detailed measurement of brine penetration into tills and clays with emphasis on a search for movement through fractures, and on permeability changes due to brine.

The Groundwater and Contaminants Project is involved in other collaborative research programs. In conjunction with Alberta Agriculture, the University of Saskatchewan and the Saskatchewan Research Council, NHRI scientists are assessing the usefulness of naturally occurring isotopes to characterize the confining nature of Cretaceous shales, and in collaboration with the Universities of Saskatchewan and Calgary and with Alberta Agriculture they are investigating the sources and dynamics of sulphur in the prairie environment.

Technician Carol Casey operates the scanning electron microscope. The SEM provides state-of-the-art capability in high-resolution photomicrography and is used in a wide variety of environmental research projects.

TECHNICAL SUPPORT

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K.J. Supeene
M.J. Waiser

Technical support staff operate two service laboratories and give direct support to the research studies of both projects within the Division. In the past year, the Central Chemical laboratory provided analytical support in such diverse fields as groundwater characterization, paleoglaciology, and herbicide fate in an artificial aquifer facility. Method development activities concentrated on improved measurement of low level anions, low level metals and analysis of diclofop (acid and methyl) in water and sediment extracts. Laboratory staff provided advice on analytical methods to various laboratories of the University of Saskatchewan and the Saskatchewan Research Council.

The Scanning Electron Microscope (SEM) provides state-of-the-art capability in high-resolution photomicrography, energy dispersive X-ray analysis and computerized feature analysis. The SEM contributed to many research studies including analysis of mineral composition, reaction and changes in acid mine drainage samples, fluidized bed combustion wastes in an artificial aquifer, and analysis of sediments from Turkey Lakes and Fort Simpson, NWT. The feature analysis capabilities have been applied to grain size distribution in sediment studies and laboratory glass bead calibrations, while SEM micrographs have been used to examine algae in water and sediment samples. Other technical staff have conducted numerous field, laboratory and data analysis assignments in aquatic biology/chemistry and groundwater chemistry and flow.

Scientists installing equipment at an NHRI research site in Canada's North.

Science Liaison Division

The Science Liaison Division is responsible for communicating scientific information to all levels of government, the public, and the scientific community through conferences, publications, displays, seminars and the media. The Division also provides support to NHRI scientific personnel in the areas of library and archival services, graphics and publications, computers, and instrument design and construction.

PUBLICATIONS, CONFERENCES AND SEMINARS.

Several report series are now established at NHRI: a contract report series, a symposium series, and a contribution series composed of reports and papers produced by scientific and technical staff. In 1990, two publications in a new science report series were released: the first is a review of research on northern hydrology entitled "Northern Hydrology : Canadian Perspectives," and the second presents an overview of research needs in river ice jam management. More science reports are planned for the coming year, including a collection of international perspectives on northern hydrology.

The NHRI seminar series continues to thrive with more than a dozen speakers visiting the Institute in the past year to give seminars on their recent research. Two international conferences, the Northern Hydrology Symposium and a conference on Aquatic Ecosystems in Semi-Arid Regions, took place in 1990 and the Division played an active role in their planning and organization. Divisional staff also assisted in organizing workshops on pesticides, remote sensing in hydrology, and environmental interactions in the Mackenzie Delta. Collected papers from several of these meetings have been printed and distributed.

LIBRARY

The library provides specialized information retrieval services in support of the Centre's research projects. Scientific and technical personnel have access to all major scientific databases for on-line searching, verification of citations, and current awareness services. This past year, four databases on CD ROM have been acquired: Arctic and Antarctic Regions, Water Resources Abstracts, Georef, and Aquatic Sciences and Fisheries Abstracts. A project to incorporate NHRI's collection of snow and ice reprints into the main library database continues.

COMPUTATION SECTION

Systems personnel provide a wide range of hardware and software support services to NHRI personnel. Services include customized programming, system management and user support for DOTS (Departmental Office Technology System), management of the Local Area Network, advice and assistance on personal computer problems, and preparation of engineering proposals for large projects.

The section's primary function is to provide computer support directly to research projects. During the past year, software development projects have included a data collection system to count and measure microscopic life and prepare summary statistics, a computer simulation of algal growth in research troughs demonstrated at GATE '90, and a data acquisition system used in determining river ice strength during break-up. Staff have assisted scientists and technicians with complex data analysis and provided expertise in the use of computer tools to perform sophisticated data manipulation, including the cross-correlation of sea-surface temperatures with glacier data, graphical presentation of data on river ice break-up, and preparation and presentation of data from various lab and field instruments.

STAFF

C.S.L. Ommanney, Chief (until April 1990)

A.D. Stanley, Chief (from May 1990)

P. Trischuk, Secretary

J.A. Banner
R.O. Christie
B.J. Doell
P.K. Gregory
T.W. Maxin
D.M. McKnight
J. Mollison
D. Peters
D. Schroeder
L.E. Watson

Inside the drill dome at the Eclipse site, Saint Elias Mountains, Michael Demuth and Art Dalton operate the Canadian-Rufli-Rand Ice Core Drill. The Instrument Technology Section of the Science Liaison Division designed and built a monitoring system to provide feedback on drill location, speed, and depth.

INSTRUMENT TECHNOLOGY SECTION.

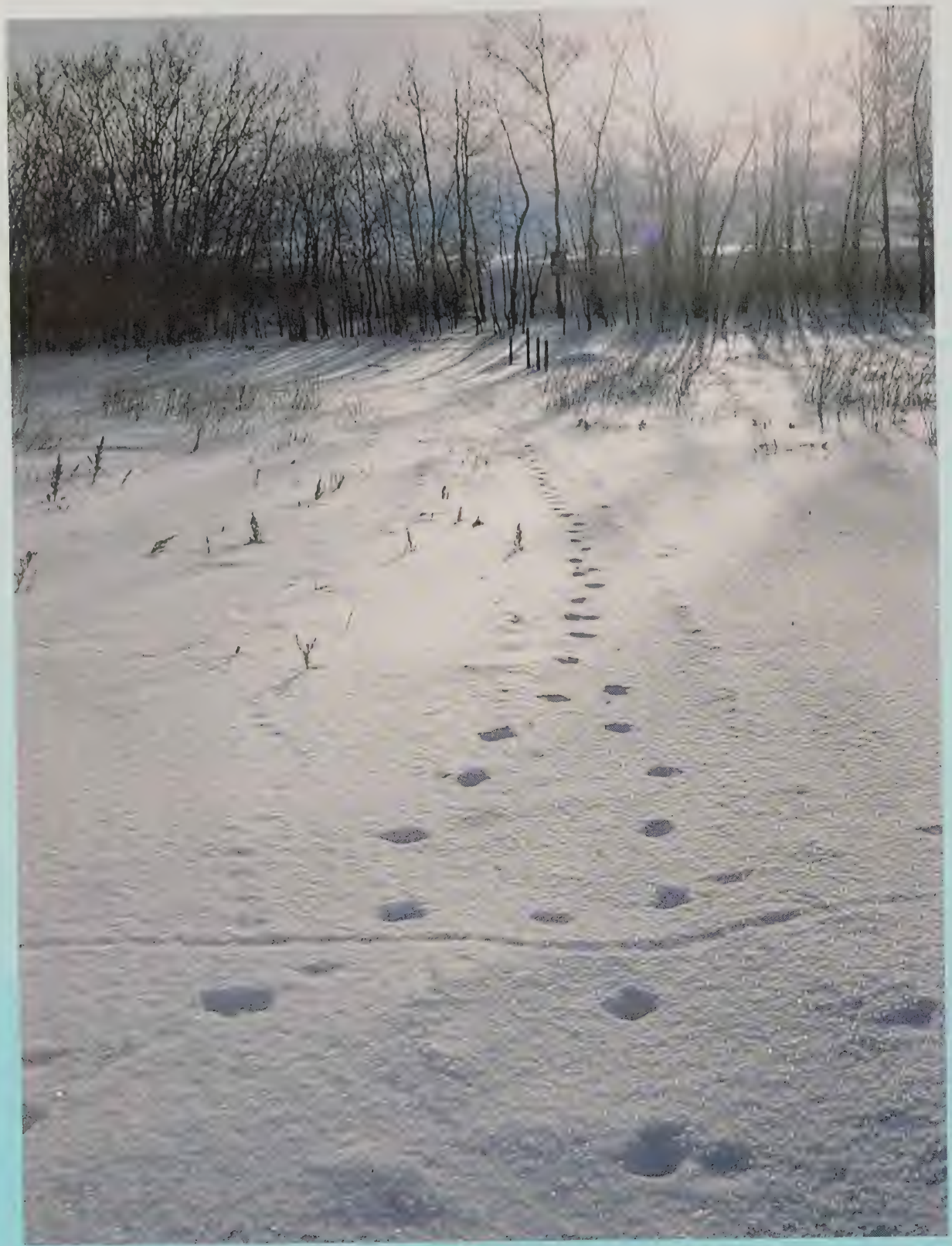
This section provides a centre of expertise for the development of instrumentation and experimental apparatus. It supports the Institute's scientific programs by helping in the selection of specialized equipment, making recommendations, and modifying instrumentation to suit particular requirements. Unique in-house research instrumentation is designed and developed to provide new capabilities for researchers in their data acquisition and analysis. Staff have skills in electronic and mechanical design, testing, calibration and fabrication. In-house facilities include machine shop machining, carpentry, welding (gas and tig), traceable calibration, electronics development and computing support. Approximately 230 research jobs were supported during the annual report period. Major projects include the design and fabrication of a cantilever ice beam test frame (to interface with a hydraulic load/data acquisition system designed by HSD scientists for the determination of the flexural properties of deteriorating river/lake ice); a calorimeter to measure the liquid fraction porosity of deteriorating ice during pre-breakup period; snow tensiometers to measure liquid water pressure in snow covers; and snow lysimeters for *in situ* measurements of the movement of snowmelt water percolating through arctic snow covers.

PUBLIC COMMUNICATIONS AND PUBLICITY

The Green Plan information sessions have shown that Canadians want more information about the environment and about government research programs designed to address environmental issues. Communication strategies have become a priority at NHRI and in 1990 a full-time communications officer was sent from Environment Canada with responsibilities for a wide-range of communication functions including media-monitoring, preparing press releases, organizing activities for Environment Week, and developing local media contacts. A new exhibit was created and presented at the Canadian Water Resources Association meeting in Penticton, British Columbia, at local public meetings such as National Wildlife Week, and at the GATE'90 conference in Saskatoon. In keeping with NHRI's goal of communicating information to the general public, staff at the Institute contributed to a series of public lectures held by the Meewasin Valley Authority in Saskatoon.

GRAPHICS

An integral part of the communication strategy, this section provides a full-range graphic arts service, including printing, photography, drafting and illustration, as well as a consulting service for planning and coordinating visual communication requirements. Preliminary designs, layouts and detailed specifications are prepared for projects, and contracts are then issued for their completion. As demand for visual communication increases, new technologies and developments in the graphic industry are researched and incorporated where required. The Publications and Graphics Section is responsible also for the design and production of brochures, reports, and published proceedings associated with the many conferences sponsored by the Centre. In 1990, a display entitled "Exploring our Water" and a corresponding brochure were developed. These have been used at expositions, science fairs, and conferences to enhance public and scientific awareness of NHRC's research programs.



Finance And Administration

The Finance and Administration Division provides administrative and financial services, materiel management, and building property management to NHRI staff. The Division also provides support services to two components of the Atmospheric Environment Service and to staff of the Water Quality Branch of the Inland Waters Directorate located in the National Hydrology Research Centre.

ADMINISTRATIVE SERVICES

A comprehensive range of administrative services are provided to the Director and Divisions of the National Hydrology Research Centre, including the compilation of conference and overseas travel plans, and the preparation of the main estimates. Staff also chair the contract review committee and serve on the computer, health and safety, fire and emergency, and labour management committees. The Division administers a variety of administrative, financial and human resource acts, regulations, policies and procedures, including the Access to Information Act. Staff manage numerous reporting systems on the utilization of human, financial and materiel resources.

BUILDING AND PROPERTY MANAGEMENT

The National Hydrology Research Centre is situated on a 2.5 ha parcel of land within the Innovation Place Research Park north of the campus of the University of Saskatchewan in Saskatoon. The building has a total area of 10,975 m^2, consisting of two major floor levels with a partial third floor containing mechanical equipment. A laboratory service spine running in an east-west direction bisects the building.

Directly adjacent to each side of this spine are laboratories, served on the opposite side by corridors in which offices, workrooms and laboratory support spaces are located. Additional administrative space is situated at the south end of the building, while shop/warehouse space is at the north end.

A complex computer system provides a broad range of data gathering, security, and safety features as well as automatic control capabilities suitable for heating, ventilating, and air conditioning and monitoring of the building.

The Building and Property Management Section is responsible for the physical operation and maintenance of the building, equipment, grounds and parking lots within the confines of the National Hydrology Research Centre. It also provides technical assistance, building modifications, and installation of specialized equipment for the day-to-day operations of all tenants of the Centre.

FINANCIAL SERVICES SECTION

The Financial Services Section manages the Automated Financial Management and Accounting System (AFMAS) for NHRI and the Hydrometeorological Research Division. The provision of financial management services requires interaction with other federal, provincial and municipal government departments as well as with private sector companies. The section provides accounts payable/receivable services as well as budget allocation, transfer and control for all of NHRI human and financial resources, and financial information and advice to budget managers.

MATERIEL MANAGEMENT

The Materiel Management Section provides a centralized procurement service; operates a stationery store and a central warehouse; performs shipping and receiving activities; maintains an inventory control system for accountable assets; maintains and distributes common-use equipment, protective and special-use clothing, and a fleet of vehicles; provides mail, courier and facsimile services, and gives assistance concerning records management issues within the Centre.

STAFF

V. Katarey, Chief
J. Akre, Secretary

B. Badger
C. Davidson
D. Kelly
P. Kerr
K. Kuit
R. Lere
B. Lloyd
K. Sykes
B. Waldbauer

Charmaine Hrynkiw uses an optical-tracking system to gather data on wind speed and direction.

Hydrometeorological Processes Division

Atmospheric Environment Service

Climate Research Branch

Canadian Climate Centre

The past year has been a time of change for the Hydrometeorological Research Division. In January 1990, Garry Schaefer, Chief of the Scientific Services Division of the Central Region in Winnipeg, took over as Division Chief while Rick Lawford fulfilled a term appointment as Associate Director in the National Hydrology Research Institute. Under Garry's guiding hand, a number of projects came to fruition. At the end of December, he returned to Winnipeg when Rick Lawford resumed his position as Chief.

In February 1991, a reorganization of the Canadian Climate Centre placed the Division in the Climate Research Branch under the direction of John Stone. Other divisions in this Branch include the Climate Modelling and Diagnostic Studies Division, the Extended Range Forecast Division, and a special projects group responsible for remote sensing activities and the work of the Boreal Ecological Study. Although this reorganization brought no major changes, the Division is now focusing more of its research efforts on basic hydrometeorological processes. Staff continue to rely heavily on the support of divisional secretary Sandra Forsberg and technician Dan Matthews. During the year, seven students were employed in the Division as well as other term employees, including programmers and a meteorologist. In September 1990, Dr. Thian Yew Gan, a Postdoctoral Fellow, also joined the Division.

During the first part of 1991, efforts were directed to obtaining adequate resources for the Regional Evaporation Study, preparing a science plan for Canadian activities under he Global Energy and Water Experiment (GEWEX), and contributing to the planning activities of the Canadian Climate Centre. As program committee chairman, Rick Lawford assisted with the organization of the scientific program for the 25th Congress of the Canadian Meteorological and Oceanographic Society. He also organized the global change program of Waterscapes '91.

The Division collaborates internationally on several projects. It participated in the Canada/U.S. Symposium on Climate Variability and Change on the Great Plains, co-sponsored by the U.S. National Climate Program Office, the Canadian Climate Program, the Inland Waters Directorate and the High Plains Climate Centre. A member of the Science Panel for GCIP (GEWEX Continental Scale International Project), Rick Lawford attended a planning meeting in Reston, Virginia in October 1990. He continues his involvement in an IGBP project to compare the responses of the northern and southern hemisphere to global change. Dr. Geoff Kite participated in an IJC Advisory Task Force on Great Lakes Water Levels Statistics and served as a member of a joint IAHS/WMO committee for Macroscale Hydrologic Modelling. Les Welsh and Geoff Kite are participating in the Canadian GEWEX writing team.

The Division's activities fall into four main areas: evaporation studies, precipitation studies, hydrometeorological models, and hydroclimatology. It acts also as a research broker, managing contracts which are funded primarily by other agencies, and using third party revenues to supplement the A-Base for studies within the Division. Collaborators include the National Hydrology Research Institute, Ducks Unlimited, the Canadian Wildlife Service, the Prairie Farm Rehabilitation Administration, Manitoba Hydro, British Columbia Hydro and Ministry of Environment, the Western Region of the Inland Waters Directorate, the Ontario Region of DOE and the Evaluation Branch of Agriculture Canada. Research was contracted to the Saskatchewan Research Council, McMaster University and the Universities of British Columbia, Calgary, Saskatchewan, Waterloo, and Laval.

STAFF

G. Schaefer, Chief
(until December 1990)

R. Lawford, Chief
(from January 1991)

S.Forsberg, Secretary

D. Bauer
J. Eley
G. Kite
D. Matthews
G. Strong
L. Welsh

Evaporation Processes and Mesoscale Research

G.S. Strong
S. Macpherson

With Dr. Geoff Strong as leader, the evaporation and mesoscale research project investigates regional evaporation processes on the Prairies, the role of local evaporation in convective precipitation, and the mesoscale dynamics which influence or control the balance between evaporation and precipitation. The main study, the Regional Evaporation Study (RES), is one of several collaborative projects aimed at improving our understanding of evaporation at all scales. Its objectives are to measure diurnal changes in the gross daily evaporation at the regional scale through three-dimensional estimates of the moisture balance; to compare RES evaporation estimates with those of other techniques; to develop land-use criteria for partitioning regional evaporation estimates by source; and to evaluate the role of local evaporation in the production of convective precipitation on the Prairies.

Successful field tests were carried out during July and August, 1990 at Vanscoy and Kenaston and a full field program will begin in the summer of 1991. RES and its collaborative studies will directly benefit numerical weather prediction and climate change modelling through improved understanding of evaporation processes, and through improved operational estimates of the evaporation and precipitation aspects of the water cycle.

Precipitation Processes Research

J. Eley
D. Magosse

Under the supervision of Joe Eley, the weather radar facility was used for real-time monitoring and post-analysis of a tornado that occurred near the city of Saskatoon in June 1990. Radar data was again used to define the area of a heavy rainfall event over Assiniboia, Saskatchewan in July. Also in the summer of 1990, a pilot study combined radar and a small network of recording rain gauges near Outlook to study the characteristics of convective rainfall swaths. A larger field study is planned for 1991. The facility assisted a user agency, the Irrigation Branch of Saskatchewan Water Corporation, with a trial application of radar-based rainfall maps in their irrigation advisory service in 1990. Part of the access system combined modern and traditional communications, as weekly radar rainfall maps were disseminated in weekly newspapers. The project evaluated high-resolution rainfall data applications and tested the specific utility of radar maps. Preliminary results were disseminated to irrigators through participation in an international conference on irrigation development at Lethbridge in 1990.

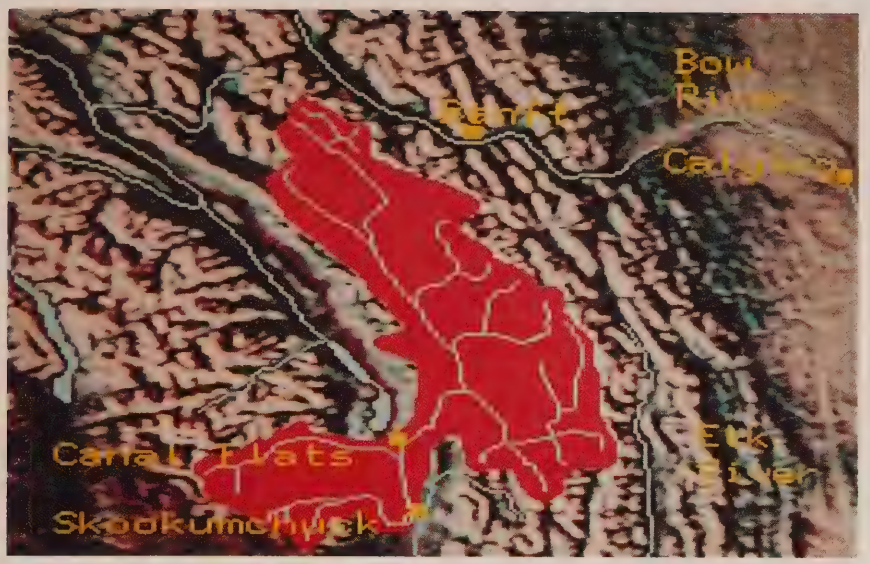
Dr. Geoff Strong prepares to release an instrumented weather balloon to obtain data for the Regional Evaporation Study. Balloons are released every 2-3 hours and provide atmospheric profiles of pressure, temperature and humidity.

Hydrometeorological Modelling

G.W. Kite
T. Gan

Hydrometeorological models are gaining increasing importance as components of the global circulation models used to assess the impact of possible future climatic changes. Dr. Geoff Kite is conducting research into the use of satellite data for such models in western Canada, three of which are being developed and tested for prairie and mountain watersheds. A lumped model is complete and work continues under contract to the University of Quebec to develop a distributed model.

In cooperation with Manitoba Hydro and the University of Waterloo, a third semi-distributed model using satellite-derived land classifications is being developed with a new optimization routine and multi-basin capability added.



An NOAA satellite image of the Kootenay Basin used to derive cloud and snow data for use in the SLURP Watershed Model.

This project will provide more accurate hydrometeorological models for both research and water resources management and a better understanding of how to use data from satellites. Copies of the model have been requested by government agencies and consulting companies throughout Canada, the U.S.A., Europe and Asia.

In September, 1990, Dr. Thian Yew Gan, joined the Division from the Asian Institute of Technology, Bangkok, as a Post-Doctoral Fellow to work on the modelling study. In May 1990, within three months of the successful Workshop on Applications of Remote Sensing in Hydrology, the 386 page proceedings was prepared, printed and distributed to the 60 participating scientists.

Hydroclimatology

L. Welsh
D.J. Bauer
J. Knox

Climatological and Hydrologic Variability and Change in the Red River Basin

A joint effort between the United States Geological Survey (USGS) North Dakota District Office (Gregg Wiche) and the Canadian Climate Centre (Les Welsh and John Knox), the CliRed project will characterize the relationship of wet and dry hydrologic and climatological periods in the Red River basin to hemispheric upper atmospheric patterns in order to improve our understanding of the atmospheric circulation controls of extreme streamflow events. A database of 1947-89 bimonthly precipitation and period-of-record annual streamflow events was assembled and used to delineate extreme wet and dry periods. Maps of average hemispheric 50 kPa upper atmospheric pressure surface heights were then constructed for the particular collective wet and dry periods, thus creating composite charts indicative of large-scale atmospheric flow. These episodes are now being analyzed for characteristic patterns which relate to the wet and dry surface events in the Red River Basin.

Drought Characterization

Don Bauer continued the drought characterization project to discover means to describe the temporal and spatial variability and trends of meteorological drought, especially for the North American Prairie. A method of gap-filling precipitation data was tested and applied in the creation of a database of precipitation time series for Saskatchewan crop districts. Another aspect of the project was a study of the feasibility of using proxy data to extend the drought time series on the Canadian Prairies. This study was contracted to Professor L. Nkendirim of the University of Calgary, with a report soon to be printed.

Collaborative Studies

Socioeconomic and Environmental Impacts of the 1988 Drought in Saskatchewan and Manitoba.

The drought of 1988 had severe impacts not only on the agricultural sector, but also on wildlife, forestry, fishery, energy, and water resources. To ensure that relevant information about this extreme drought is retained as an important case study, the Division and the National Hydrology Research Institute are managing a study, conducted principally by the Saskatchewan Research Council and funded by several stakeholder agencies. The contractors are assembling and describing a substantial data set and report documenting numerous aspects of the drought impacts on Saskatchewan and Manitoba.

Climate/Wetlands Study

The first phase of the climate/wetlands study continued through 1990/91, and Dr. M.K. Woo and Bob Rowsell of McMaster University are now developing a descriptive model based on their analysis of two years of data collected at a wetland near St. Denis, Saskatchewan. The project is funded by a number of agencies including Ducks Unlimited, the Canadian Wildlife Service, and the National Hydrology Research Institute, as well as by the Hydrometeorological Processes Division. The research has been contracted to McMaster University, with Garry Schaefer, Geoff Strong and Rick Lawford from the Division providing guidance. Results will be useful in assessing the impact that climate warming may have for the shallow wetlands of the Canadian prairies.

Climate and Hydrology in British Columbia

Two studies have been carried out under contract to the University of British Columbia: one on climate variability and change, the other on the hydrometeorology of British Columbia. The first, funded by the Canadian Climate Centre, the Institute of Ocean Sciences, the Pacific Biological Research Station and the Pacific Region of the Inland Waters Directorate, dealt with the possible effects of climate change on the water resources, coastal currents and fisheries of British Columbia, as well as with the difficulties of carrying out climate impact assessments in a region of complex terrain. The second study, which was funded by BC Hydro, the BC Ministry of the Environment and the Canadian Climate Centre, investigated the effects of changing synoptic atmospheric circulation patterns on abnormally moist or dry periods. A report on the first study is expected during the Spring of 1991 and the second study should be completed in the Fall.

Saskatchewan Inspection Office

Central Region, Atmospheric Environment Service

STAFF

K. Leek

N. Arvidson
T. Benko
J. Mravnik
G. Toffelmire

The Saskatchewan Inspection Office, a part of the Atmospheric Environment Service (Central Region), is responsible for the installation, maintenance, and regular inspection of weather stations in Saskatchewan and four other sites in the High Arctic Islands of the Northwest Territories. The office is staffed by three meteorological inspectors, two electronic technicians and a summer student.

The area served by the office is comprised of 23 mainline weather stations, 10 automatic weather stations, and approximately 240 volunteer weather observing stations situated in small towns and on farms around the province.

About one week is required for a full inspection of the equipment and programs at a mainline station, while inspections of automatic stations require only one day, but are performed more frequently. AES also maintains a Canadian Air and Precipitation Monitoring Network (CAPMoN) station at Cree Lake, Saskatchewan, and this requires four visits annually by inspection staff. Electronic technicians share responsibility for the maintenance of the electronics at seven automatic stations, the weather radar equipment at Elbow, Sask., and the weather radio equipment at the Saskatoon airport.

Water Quality Branch

Analytical Services Division

The Water Quality Branch (WQB), Inland Waters Directorate undertakes activities such as maintaining an inventory of baseline water information, identifying pollution problems, monitoring inter-jurisdictional waters and determining compliance with water-quality objectives. WQB has offices in each of the five regional offices of the Inland Waters Directorate across Canada.

The Analytical Services Division of WQB for the Western and Northern Region is located at the National Hydrology Research Centre in Saskatoon and reports to regional headquarters in Regina. The Division provides nutrient analysis of water in support of WQB survey and monitoring programs. Staff maintain a 280 m^2 laboratory, a computer terminal room, a shipping and receiving area and four offices. Division computer terminals are linked to the regional WQB MicroVax II computer in Regina.

The Division consists of three chemists and three laboratory technicians. Employees hired through contracting-in arrangements provide most of the shipping/receiving and sample bottle-washing services, and they contribute to some of the analytical work.

STAFF

G.P. Lee

F. Cyr
M.B. Holliday
K. Krainz
R.J. Scott

Routine Services

In addition to its main task of nutrient analysis, the Division provides assistance to Federal-Provincial cost-shared water quality monitoring programs in the Western and Northern Region. It provides analytical work for other agencies on a cost-recovery basis, under formal or co-operative arrangements. The Division laboratory is also capable of measuring levels of pH, alkalinity, physical parameters, chlorophyll a, cyanide, and phenolics.

On June 1 1990, following the successful evaluation of ICP methodology for determination of boron in prairie water, the laboratory eliminated the analysis of boron by the automated carminic acid method. The latter is subject to interferences.

Through increased automation, the group has been able to analyse a larger number of samples without sacrificing data quality. High-speed continuous flow analyses (TRAACS) systems have been acquired to improve both the quality and productivity of analyses. In 1990-91, the laboratory received 2,726 samples and performed 39,011 tests.

Analytical Consulting Services and Broad Spectrum Analysis

The Analytical Services Division provides consulting expertise and leadership on sampling and analytical strategies for organic contaminants in support of WQB activities and research projects at the National Hydrology Research Centre. The laboratory supports new initiatives in interpretive reporting required for Broad Spectrum Analysis.

This method analyses for the largest possible number of chemicals in a sample, and thus provides maximum information on its organic composition. Its usefulness is based on the ability to observe changes in water quality data from differences between chromatograms. It is an alternative to target compound analysis.


R.G. Lawford


C. Heseltine


Dr T.M. Dick


P. Richard


S.D. Baird

DIRECTOR'S OFFICE


Dr W. Nicholaichuk


Dr R.D. Robarts


C.S.L. Ommanney


Dr T.D. Prowse


Dr B.C. Kenney


Dr G. Holdsworth


Dr R.I. Perla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Dr M.J. Hendry


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C.A. Casey

R.J. Reid

N. Hedstrom

M. Griffin

K.J. Supeene

M. Ferguson

K.M. Peru

D. Sonmor

HYDROLOGICAL SCIENCES

ENVIRONMENTAL SCIENCES

NHRC 90/91

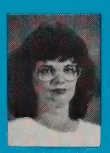

Dr A.D. Stanley


P.D. Trischuk


V.J. Katarey


J.L. Akre


D.G. Schaefer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N. Arvidson


F. Cyr


P.K. Gregory


B.J. Doell


D. Kelly


C. Davidson


Dr G.W. Kite


Dr G.S. Strong


G. Toffelmire


R.J. Scott


Dr L.E. Watson


D. McKnight


B.A. Waldbauer


P.A. Kerr


D.J. Bauer


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J. Mravnik


B. Holliday


D. Schroeder


D. Peters


B.J. Badger


B.M. Lloyd


D.W. Matthews


F.J. Eley


T. Benko


K. Krainz


R.O. Christie


J.A. Banner

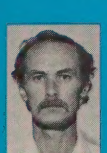

K. Kuit


K. Sykes

HYDROMETEOROLOGICAL PROCESSES

SASKATCHEWAN INSPECTION OFFICE


T.W. Maxin


J. Mollison

R.J. Lere

SCIENCE LIAISON

FINANCE AND ADMINISTRATION

ATMOSPHERIC ENVIRONMENT

WATER QUALITY

Canada

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Oxford.
ESSELTE
10%